APPENDIX B

DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

Roadside Pest Management Program Final Ecological and Human Health Risk Assessment

Prepared for:

Texas Department of Transportation

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TABLE OF CONTENTS

Tables

Figures

1.0 INTRODUCTION

This Ecological Risk Assessment (ERA) and Human Health Risk Assessment (HHRA) are presented as a part of the Texas Department of Transportation's (TxDOT) effort to supplement its Final Environmental Impact Statement (FEIS) for its Roadside Pest Management Program. TxDOT completed the FEIS in 1996 and since that time, new techniques, chemicals, and procedures have become available. A supplement is necessary in order to fully disclose and inform the public on the environmental impacts of the Pest Management Program and to adhere to state rules.

The report has three major sections: 1) chemical-specific information - Section 2.0; 2) ERA - Section 3.0; and 3) HHRA - Section 4.0. Both the ERA and HHRA evaluate several different types of exposure, which involve numerous calculations. Worksheets containing these calculations are included in separate ecological and human health spreadsheets provided in Volume II, Appendix D.

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2.0 CHEMICAL-SPECIFIC INFORMATION

This section provides chemical-specific information about the various pest management chemical products used or planned for use by TxDOT in its Roadside Pest Management Program. Specifically, this section summarizes the properties of each of the active ingredients of chemicals used to treat pest species, including the following: 1) physical/chemical properties; 2) application methods; 3) application rates; and 4) dilution rates.

2.1 PHYSICAL/CHEMICAL PROPERTIES

Physical and chemical properties for active ingredients found in formulations used by TxDOT in its Roadside Pest Management Program that are environmentally significant and considered relevant to the ERA and HHRA (Sections 3.0 and 4.0) are summarized in **Table 2-1**. The properties necessary for quantifying exposures include molecular weight, log K_{ow}, BCFs, and foliar half-life.

Chemical Abstract Service (CAS) numbers were obtained and used to determine the molecular weights and log K_{ow} values. Log K_{ow} values were primarily obtained from the United States Department of Agriculture (USDA) Agricultural Research Service (ARS) Pesticide Database, product Material Safety Data Sheets (MSDSs), and Syracuse Research Corporation (SRC) databases (SRC, 2004a and 2004b). BCFs for each chemical were calculated using the following regression equation (**Equation 2-1**) from Lyman et al. (1990):

$$\log BCF = (0.76)(\log K_{ow}) - 0.23$$

where K_{ow} is the octanol-water partition coefficient.

The foliar half-lives used in this report coincide with those used in the GLEAMS Model (web-based application National Agricultural Pesticide Risk Assessment, World Wide Web [NAPRA WWW]), Groundwater Loading Effects of Agricultural Management Systems Version 3.0) (NAPRA GLEAMS) (Baker, 2006). These values were obtained from USDA Forest Service Risk Assessments or estimated based on a soil half-life. In the case where foliar half-life values were not located in the literature for active ingredients (specifically, sulfometuron [Outrider], fluroxypyr [Vista], chlorsulfuron [Landmark MP], methoprene [Altosid XR], amino pyralid [Milestone VM], and

fenoxycarb [Award]), a conservative assumption was made for NAPRA GLEAMS to use 75 percent of the soil half-life.

2.2 APPLICATION METHODS

In this report, two conventional application methods are considered: 1) directed foliar (backpack and handgun application); and 2) broadcast ground spray (or low boom ground spray). Backpack application generally consists of selective foliar applications where the chemical sprayer is carried by backpack and the chemical is applied to selected target vegetation. Handgun spray application from a truck also can consist of selective foliar applications (i.e., Aquamaster). TxDOT generally uses low-boom, ground-spray applications for treating the right of way (ROW). Spray equipment mounted on trucks is used to apply the chemicals on either side of the roadway. **Table 2-2** summarizes the application methods for products evaluated in this document.

With the exception of methoprene (Altosid XR), triclopyr-butoxyethyl ester (triclopyr-BEE; Pathfinder II), and glyphosate-isopropylamine salt (Aquamaster), broadcast ground spray was assumed for all pest control chemicals. Altosid XR is applied directly to surface water as a briquette. Aquamaster is applied directly to emergent aquatic vegetation (direct foliar application) by handgun spray units, while Pathfinder II is applied by direct spray via backpack for basal bark treatments.

2.3 APPLICATION RATES AND DILUTIONS

The specific application rates used in a backpack or ground spray application vary according to local conditions and the nature of the target vegetation. The application rates used in this report for each chemical product are those specific to TxDOT's Roadside Pest Management Program. Product application rates are provided in **Table 2-2**.

Application rates evaluated for each chemical are given either in pounds active ingredient (a.i.)/acre or pounds acid equivalent (a.e.)/acre. The active ingredient of a chemical formulation is the component responsible for its toxicity or ability to control the target pest. The active ingredient is always identified on the label by either common name or chemical name. The active ingredient statement may also include information about how the product is formulated and the amount of active ingredient contained in a gallon or pound of formulated product.

TABLE 2-1
PHYSICAL AND CHEMICAL PROPERTIES

Active Ingredient	Product [1]	CAS Number	USEPA Pesticide Chemical Code	Molecular Weight (grams/mole)		Log K_{ow} (unitless)		Bioconcentration Factor [2] (L/kg)		Foliar Half-Life (Days)		Solubility (mg/L)	
				Value	Reference	Value	Reference	Value	Reference	Value	Reference	Value	Reference
Glyphosate (isopropylamine salt)	Roundup Pro and Aquamaster	38641-94-0	103601	288.18	CambridgeSoft Corp, 2004	-4.85	USDA, 2003a	<1.0	Lyman et al., 1990	10	USDA, 2003a	900,000	USDA, 1993a
Glyphosate (potassium salt)	Roundup Original Max	70901-20-1	103613	207.16	CambridgeSoft Corp, 2004	-3.0	USDA, 2003a	<1.0	Lyman et al., 1990	10	USDA, 2003a	Not available [3]	Not Available [3]
Sulfometuron methyl	Oust XP and Landmark MP	74222-97-2	122001	364.4	USDA, 2005	-0.46	USDA, 2005	<1.0	Lyman et al., 1990	10	USDA, 2004a	244 (25 deg. C; pH = 7.0)	USEPA, 2005
Sulfosulfuron	Outrider	141776-32-1	85601	470.47	Health Canada, 1998	0.99	SRC, 2004a	3.3	Lyman et al., 1990	38	Baker, 2005	18 (20 deg. C; pH = 5.0)	SRC, 2004b
Metsulfuron methyl	Escort XP	74223-63-6	122010	381.4	USDA, 2005	-1.7	USDA, 2005	<1.0	Lyman et al., 1990	30	USDA, 2004b	9,500 (25 deg. C; pH = 7.0)	SRC, 2004b
Fluroxypyr	Vista	81406-37-3	128968	367.25	CambridgeSoft Corp, 2004	5.07	USEPA, 1998	4,200	Lyman et al., 1990	24	Baker, 2005	0.09 (20 deg. C)	SRC, 2004b
Triclopyr (butoxyethyl ester)	Pathfinder II	64700-56-7	116004	356.63	CambridgeSoft Corp, 2004	4.01	SRC, 2004a	657	Lyman et al., 1990	15	USDA, 2003b	23	USDA, 1993b
Triclopyr (triethylamine salt)	Garlan 3a	57213-69-1	116002	357.66	CambridgeSoft Corp, 2004	1.5	SRC, 2004a	8.1	Lyman et al., 1990	15	USDA, 2003b	2,100,000	USEPA, 2005
Clopyralid	Transline	57754-85-5	117401	253.1	Budavari, 1989	-2.63	Dow AgroSciences, 1998	<1.0	Lyman et al., 1990	2	USDA, 2004c	9,000 (25 deg. C)	USDA, 2005
Chlorsulfuron	Landmark MP	64902-72-3	118601	357.8	USDA, 2005	-1.0	USDA, 2005	<1.0	Lyman et al., 1990	30	Baker, 2005	28,000 (25 deg. C; pH = 7.0)	SRC, 2004b
Methoprene	Altosid XR	40596-69-8	105401	310.5	Extoxnet, 1996	5.5	SRC, 2004a	8,913	Lyman et al., 1990	7	Baker, 2005	1.4 (25 deg. C)	SRC, 2004b
Amino pyralid	Milestone VM	150114-71-9	117408	207.03	Dow AgroSciences, 2005	-2.87	Dow AgroSciences, 2005	<1.0	Lyman et al., 1990	23	Baker, 2005	2,480	Baker, 2005
Imazapyr	Habitat	81510-83-0	128829	320.4	BASF Corp., 2004	0.1	USDA, 2005	<1.0	Lyman et al., 1990	26	USDA, 2004d	650,000	USDA, 2005
Fenoxycarb	Award	72490-01-8	125301	301.34	USDA, 2005	4.07	USDA, 2005	730	Lyman et al., 1990	1	Baker, 2005	6 (20 deg. C)	SRC, 2004b

Notes:
USDA = United States Department of Agriculture
USEPA = United States Environmental Protection Agency
SRC = Syracuse Research Corporation
deg. C = degrees Celcius
[1] Roundup Original Max is not currently used by TxDOT in its Roadside Pest Management Program. This product may serve as a replacement for Roundup Pro in the future.
[2] Bioconcentration factor estimated using a regression equation from Lyman et al. (1990): log BCF = (0.76)(log K_{ow}) - 0.23
[3] A water solubility value could not be identified from the literature. The MSDS for Roundup Original Max (Monsanto Company, 2005) reported that the active ingredient is soluble in water.

Source: Project Team

TABLE 2-2
APPLICATION RATES

Active Ingredient	Product	Formulation	Percent Active Ingredient	Method of Application	Product Application Rate			Active Ingredient Application Rate		
					Application Rate No. 1	Application Rate No. 2	Application Rate No. 3	Application Rate No. 1	Application Rate No. 2	Application Rate No. 3
Glyphosate (isopropylamine salt)	Roundup Pro	Liquid	31% (a.e.)	Hand gun, rope wick, and low boom ground spray	8 oz./acre	16 oz./acre	4 qt./acre	0.1875 lb a.e./acre	0.3735 lb a.e./acre	3 lb a.e./acre
	Aquamaster	Liquid	39.9% (a.e.)	Handgun	2 gal./acre	---	---	8 lb a.e./acre	---	---
Glyphosate (potassium salt)	Roundup Original Max (1)	Liquid	39.8% (a.e.)	Handgun and low boom ground spray	5.33 oz./acre	10.67 oz./acre	2.67 qt./acre	0.1875 lb a.e./acre	0.3735 lb a.e./acre	3 lb a.e./acre
Sulfometuron methyl	Oust XP	Solid	75% (a.i.)	Low boom ground spray	2 oz./acre	---	---	0.09375 lb a.e./acre	---	---
	Landmark MP	Solid	56.25% (a.i.)	Low boom ground spray	2 oz./acre	1 oz./acre	---	0.0703 lb a.i./acre	0.0352 lb a.i./acre	---
Sulfosulfuron	Outrider	Solid	75% (a.i.)	Low boom ground spray	1.33 oz./acre	---	---	0.0623 lb a.i./acre	---	---
Metsulfuron methyl	Escort XP	Solid	60% (a.i.)	low boom ground spray	1 oz./acre	3 oz./acre	---	0.0375 lb a.i./acre	0.1125 lb a.i./acre	---
Fluroxypyr	Vista	Liquid	18.2% (a.e.)	Low boom ground spray	10 oz./acre	---	---	0.1174 lb a.e./acre	---	---
Triclopyr (butoxyethyl ester)	Pathfinder II (2)	Liquid	9.81% (a.e.)	Backpack	2.5 gal./acre	5 gal./acre	---	1.882 lb a.e./acre	3.764 lb a.e./acre	---
Triclopyr (triethylamine salt)	Garlon 3a	Liquid	31.8% (a.e.)	Low boom ground spray	1 qt./acre	---	---	0.75 lb a.e./acre	---	---
Clopyralid	Transline	Liquid	31% (a.e.)	Handgun or low boom ground spray	10 oz./acre	21 oz./acre	---	0.2345 lb a.e./acre	0.4925 lb a.e./acre	---
Chlorsulfuron	Landmark MP	Solid	18.75% (a.i.)	Low boom ground spray	2 oz./acre	1 oz./acre	---	0.0234 lb a.i./acre	0.0117 lb a.i./acre	---
Methoprene	Altosid XR	Solid	2.1% (a.i.)	Applied as a briquette directly to surface water	1 briquet/200 ft^3	---	---	0.00025 lb/ft^3	---	---
Amino pyralid	Milestone VM	Liquid	21.1% (a.i.)	Low boom ground spray	7 oz./acre	---	---	0.1097 lb a.i./acre	---	---
Imazapyr	Habitat	Liquid	22.6% (a.e.)	Handgun or low boom ground spray	2 qt/acre	---	---	0.99 lb a.e./acre	---	---
Fenoxycarb	Award	Solid	1.0% (a.i.)	Handgun or low boom ground spray	1 lb/acre	---	---	0.01 lb a.i./acre	---	---

Notes:
a.e. = acid extractable
a.i. = active ingredient
ft^3 = cubic feet
gal. = gallon
lb = pound
oz. = ounce
qt. = quart
(1) Roundup Original Max is not currently used by TxDOT in its Roadside Pest Management Program. This product may serve as a replacement for Roundup Pro in the future.
(2) Basal bark application only.

Source: Project Team

Acid equivalent may be defined as that portion of a formulation that theoretically could be converted back to the corresponding or parent acid. Another definition of acid equivalent is the theoretical yield of parent acid from a chemical active ingredient that has been formulated as a derivative (esters, salts, and amines are examples of derivatives).

Based on product label information, the following active ingredients were evaluated using the acid extractable equivalent for the active ingredients: clopyralid (Transline), fluroxypyr (Vista), glyphosate (Roundup Pro, Aquamaster, and Roundup Original Max), imazapyr (Habitat), and triclopyr (Pathfinder II and Garlon 3a). The active ingredient application rates for all remaining chemicals were in pounds a.i./acre. Active ingredient application rates used in this report for quantifying exposure are provided in **Table 2-2**.

Typically, chemicals are diluted prior to field applications. Field dilutions are generally expressed as a range on the product label. Dilution rates were obtained from product labels when available. The lowest end of the field dilution range was selected for use in this report. In the event that a dilution was not available on the product label or from TxDOT, a dilution rate of 10 gallons per acre was used. This represents the lower limit of the recommended range of mixing volumes for many formulations for ground spray applications (SERA, 2001). For each chemical active ingredient, dilutions and corresponding concentrations in field solution are presented in **Table 2-3**.

TABLE 2-3
DILUTION RATES AND CONCENTRATIONS IN FIELD SOLUTION

Active Ingredient	Product (1)	Application Rate (lb/acre)	Dilution Rate (2) (gal./acre)	Concentration in Field Solution (3) (mg/mL)
Glyphosate - isopropylamine salt	Roundup Pro	0.1875	3	7.49
	Roundup Pro	0.3735	3	14.92
	Roundup Pro	3.0	3	119.8
	Aquamaster	4.0	100	4.79
Glyphosate - potassium salt (3)	Roundup Original Max	0.1875	3	7.49
	Roundup Original Max	0.3735	3	14.92
	Roundup Original Max	3.0	3	119.8
Sulfometuron methyl	Oust	0.09375	15	0.75
	Landmark MP	0.1055	10	1.26
	Landmark MP	0.3516	10	4.21

TABLE 2-3
DILUTION RATES AND CONCENTRATIONS IN FIELD SOLUTION

Active Ingredient	Product (1)	Application Rate (lb/acre)	Dilution Rate (2) (gal./acre)	Concentration in Field Solution (3) (mg/mL)
Sulfosulfuron	Outrider	0.0623	10	0.75
Metsulfuron methyl	Escort XP	0.0375	10	0.45
	Escort XP	0.1125	10	1.35
Fluroxypyr	Vista	0.1174	10	1.41
Triclopyr - butoxyethyl ester	Pathfinder II	1.882	None	89,879
	Pathfinder II	3.764	None	89,879
Triclopyr - triethylamine salt	Garlon 3a	0.75	20	4.49
Clopyralid	Transline	0.2345	10	2.81
	Transline	0.4925	10	5.9
Chlorsulfuron	Landmark MP	0.0352	10	0.42
	Landmark MP	0.1172	10	1.4
Amino Pyralid	Milestone VM	0.4775	25	2.1
Imazapyr	Habitat	0.99	5	23.72
Fenoxycarb	Award	0.01	10	0.12

Notes:
lb = pound gal. = gallon
mg = milligram mL = milliliter

(1) Application rates for Roundup Original Max assumed to be identical to current application rates for Roundup Pro. Roundup Original Max is not currently being used by TxDOT in its Roadside Pest Management Program.

(2) Dilution rates obtained from product labels and correspondence with TxDOT personnel.

(3) Values express as acid extractable (clopyralid, fluroxypyr, glyphosate - isopropylamine salt, glyphosate - potassium salt, imazapyr, and triclopyr - butoxyethhyl ester, and triclopyr - triethylamine salt) or active ingredient (sulfometuron methyl, sulfosulfuron, metsulfuron methyl, chlorsulfuron, amino pyralid, and fenoxycarb).

Source: Project Team

The concentration of each active ingredient in field solution was calculated as the application rate (lb/acre) divided by the dilution rate (gal/acre), yielding units of lb/gallon. This was converted to mg/mL using the relationship of lb/gal = 119.8 mg/mL (**Equation 2-2**):

$$C_f = \frac{AR_x}{D_x}(119.8)$$

where Cf is the concentration of chemical x in the field solution (mg/mL), ARx is the application rate of chemical x (lb/acre), and Dx is the dilution rate (gal/acre).

3.0 ECOLOGICAL RISK ASSESSMENT

This section presents an ERA for active ingredients in the various products used by TxDOT for its Roadside Pest Management Program. The ERA was conducted in four phases: 1) problem formulation; 2) ecological effects characterization; 3) exposure characterization; and 4) risk characterization. Each phase is discussed in the sections that follow.

3.1 PROBLEM FORMULATION

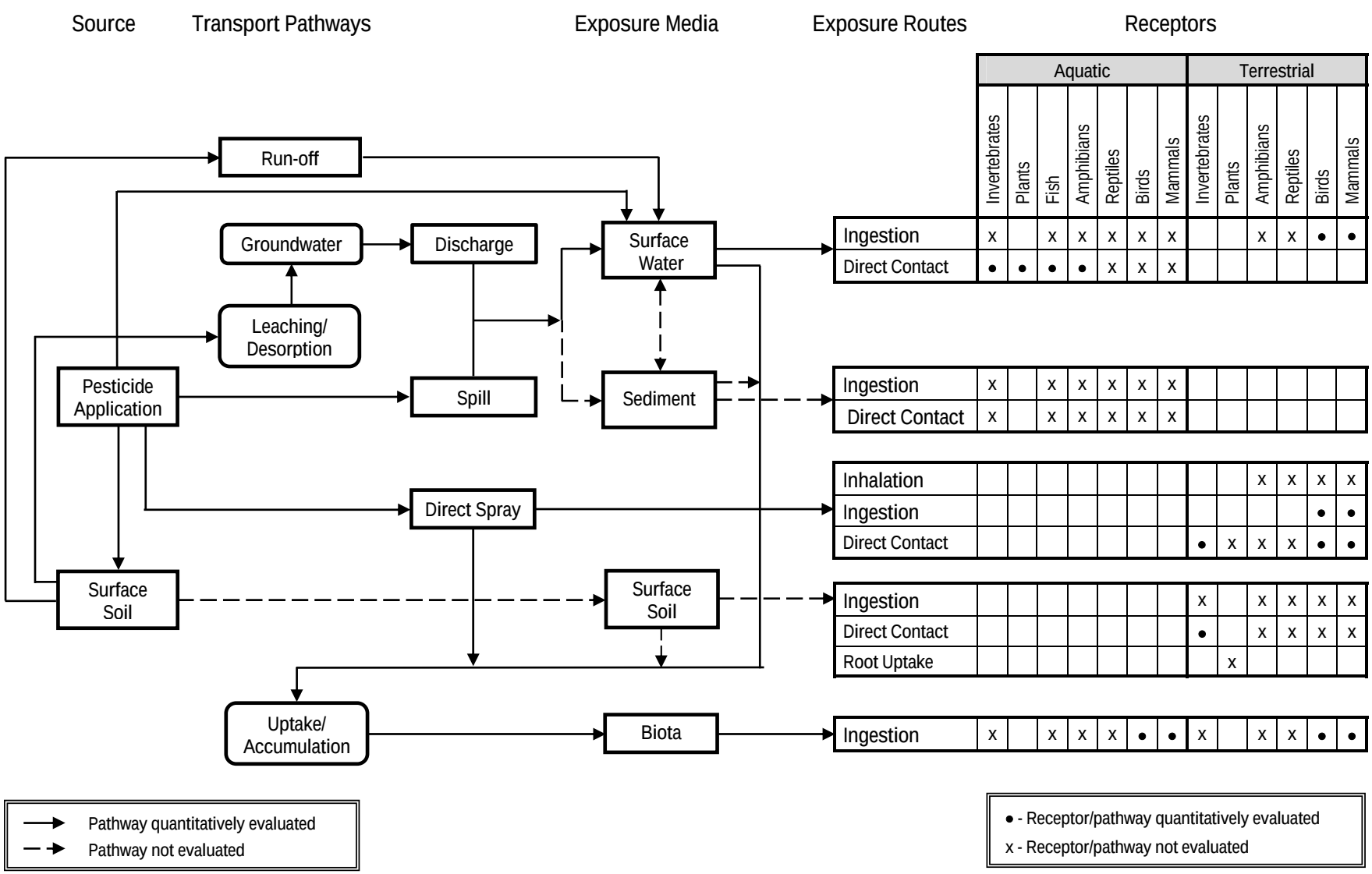
Problem formulation establishes the goals, scope, and focus of the ERA. The products of the problem formulation are 1) the conceptual model; and 2) assessment and measurement endpoints. The purpose of the conceptual model is to describe how receptors may be exposed to ecological stressors. In the case of this investigation, the ecological stressors are the various active ingredients present in the chemicals used by TxDOT in its Roadside Pest Management Program. The conceptual model is developed using information regarding potential ecological receptors, media of concern, and potential contaminant sources in conjunction with an understanding of potential transport pathways, exposure pathways, and exposure routes. The fate, transport, and toxicological properties of the chemicals are also considered during this process.

3.1.1 Conceptual Model

Figure 3-1 presents a generic conceptual model for chemical applications by TxDOT in its Roadside Pest Management Program. The conceptual model outlines relationships between the application of chemicals and exposure by ecological entities. Exposure, and thus potential risk, can only occur if each of the following conditions is met:

- A source (an entity or action that releases a stressor to the environment) must be present;
- Transport mechanisms must be available to move the stressor from the source to an exposure point;
- An exposure point must exist where ecological receptors could contact affected media; and
- An exposure route must exist whereby the stressor can be taken up by ecological receptors.

FIGURE 3-1: ECOLOGICAL CONCEPTUAL MODEL



The various application methods employed by TxDOT (i.e., low-boom, ground-spray applications, handgun-spray applications, and backpack-spray applications) represent sources of chemical releases to the environment. The primary transport pathways that describe how the chemical may be transported from the source (i.e., application methods) to an exposure point (ecologically relevant abiotic and biotic media) include the following:

- Direct spray/spray drift deposition onto non-target biota;
- Direct spray/spray drift deposition onto surface soil;
- Transfer of chemical residuals on non-target biota to upper trophic level receptors;
- Direct spray/application, spray drift deposition, or accidental spill to surface water;
- Overland transport with surface soil via surface runoff to down-gradient surface soil, surface water, and sediment;
- Leaching of chemicals from surface soil by infiltrating precipitation and transport to surface water and sediment with groundwater; and
- Uptake and bioaccumulation by biota from surface soil, surface water, and/or sediment and trophic transfer to upper trophic levels.

The potential exposure pathways identified in this bulleted list do not apply to all chemicals used by TxDOT in its Roadside Pest Management Program. Altosid XR (methoprene), a juvenile insect growth regulator used for mosquito control, is a solid (briquette) added directly to surface water. Therefore, direct spray/spray drift deposition onto non-target biota, direct spray/spray drift deposition onto surface soil, overland transport with surface soil via surface runoff to down-gradient surface soil, surface water, and sediment, and leaching of chemicals from surface soil by infiltrating precipitation and transport to surface water and sediment with groundwater are considered incomplete transport pathways. These same transport pathways are also considered incomplete for Pathfinder II (triclopyr-BEE) and Aquamaster (glyphosate-isopropylamine salt). Pathfinder II is applied directly to terrestrial vegetation (basal bark treatments) using backpack sprayers, while Aquamaster is applied directly to aquatic vegetation (i.e., emergent vegetation, including cattails and giant reed) using handgun sprayers. Because these herbicides are applied directly to target vegetation

using either a backpack sprayer (Pathfinder II) or a handgun sprayer (Aquamaster), direct spray/spray drift deposition onto non-target biota would not be expected. Direct spray/spray drift deposition onto surface soil also is unlikely when basal bark treatments or direct foliar applications to aquatic vegetation are used; therefore, migration with surface soil via surface runoff to down-gradient abiotic media and migration with groundwater to down-gradient surface water and sediment also are considered incomplete transport pathways.

An exposure route describes the specific mechanism(s) by which an ecological receptor is exposed to a chemical present in an environmental medium. The most common exposure routes are dermal contact, direct uptake, ingestion, and inhalation. Birds and mammals may be exposed to active ingredients in chemicals through: 1) the inhalation of spray particles; 2) the incidental ingestion of contaminated abiotic media (e.g., soil or sediment) during feeding or cleaning activities; 3) the ingestion of contaminated water; 4) the ingestion of contaminated plant and/or animal tissues for chemicals that have been sprayed/deposited on or bioaccumulated in food items; and/or 5) dermal contact with spray particles (direct spray) or contaminated abiotic media.

Non-target terrestrial plants may be exposed to chemicals by direct spray, spray drift deposition, and through their root surfaces during water and nutrient uptake. Terrestrial invertebrates may be exposed by direct spray, dermal contact with contaminated media (i.e., surface soil and vegetation), and ingestion of contaminated food items. Unrooted, floating aquatic plants, rooted submerged and emergent aquatic plants, and phytoplankton (e.g., algae) may be exposed to chemicals directly from the water column or (for rooted plants) from sediment. Finally, aquatic invertebrates, fish, and amphibians may be exposed to chemicals by direct contact with surface water and sediment, ingestion of surface water and sediment, and ingestion of contaminated food items.

Certain potential exposure pathways and/or routes were not evaluated by this ecological assessment, as they were considered insignificant relative to other pathways that were evaluated. For example, incidental ingestion of surface soil during feeding and preening activities was considered insignificant relative to ingestion exposures from the consumption of surface water and contaminated prey items. The specific exposure pathways evaluated by this ERA are as follows:

- Dermal contact with spray particles (direct spray) by terrestrial invertebrates (pollinators), birds, and mammals;
- Ingestion of surface water by birds and mammals;
- Ingestion of contaminated prey/food items by birds and mammals; and
- Direct contact with surface water by fish, amphibians, aquatic invertebrates, and plants.

3.1.2 Assessment and Measurement Endpoints

Two types of endpoints, assessment endpoints and measurement endpoints, are defined as part of the ERA process as are risk hypotheses or risk questions (USEPA, 1997a and 1998a). An assessment endpoint is an explicit expression of the environmental component or value that is to be protected. A measurement endpoint is a measurable ecological characteristic that is related to the component or value chosen as the assessment endpoint. The considerations for selecting assessment and measurement endpoints are summarized in USEPA (1992 and 1997a) and discussed in detail in Suter II (1989, 1990, and 1993). Risk hypotheses are testable hypotheses about the relationship among the assessment endpoints and their predicted responses when exposed to contaminants.

Endpoints in the ERA define ecological attributes that are to be protected (assessment endpoints) and a measurable characteristic of those attributes (measurement endpoints) that can be used to gauge the degree of impact that has or may occur. Assessment endpoints most often relate to attributes of biological populations or communities and are intended to focus the risk assessment on particular components of the ecosystem that could be adversely affected by chemicals (USEPA, 1997a). Assessment endpoints contain an entity (e.g., small avian herbivore) and an attribute of that entity (e.g., survival rate). Individual assessment endpoints usually encompass a group of species or populations (the receptor) with some common characteristic, such as specific exposure route or contaminant sensitivity, with the receptor then used to represent the assessment endpoint in the risk evaluation.

Assessment and measurement endpoints may involve ecological components from any level of biological organization, from individual organisms to the ecosystem itself (USEPA, 1992). Effects on individuals are important for some receptors, such as rare and endangered species; however, population and community-level effects are

typically more relevant to ecosystems. Population and community-level effects are usually difficult to evaluate directly without long-term and extensive study. However, measurement endpoint evaluations at the individual level, such as an evaluation of the effects of chemical exposure on reproduction, can be used to predict effects on an assessment endpoint at the population or community level.

The assessment endpoints, risk questions, and measurement endpoints selected for this ERA are summarized in **Table 3-1**.

TABLE 3-1
ASSESSMENT ENDPOINTS, RISK QUESTIONS, AND MEASUREMENT ENDPOINTS

Assessment Endpoint	Risk Questions	Measurement Endpoint
Terrestrial Habitat		
Survival of terrestrial invertebrate communities (pollinators - honey bees).	Are potential direct spray exposures adversely affecting terrestrial invertebrate communities (i.e., pollinators)?	Comparison of literature-derived acute toxicity endpoint values with modeled exposure doses.
Survival, growth, and/or reproduction of small avian and small mammalian populations.	Are potential direct spray exposures affecting small bird and small mammal populations? Are herbicide/insecticide concentrations in an on-site pond following an accidental spill and herbicide/insecticide concentrations in an off-site pond receiving run-off and groundwater discharges from the point of application adversely affecting small avian and mammalian populations that may be ingesting surface water?	Comparison of literature-derived acute toxicity endpoint values with modeled exposure doses for direct spray. Comparison of literature-derived acute and chronic toxicity endpoint values for survival, growth, and/or reproductive effects with modeled drinking water exposure doses.
Survival, growth, and reproduction of small avian herbivore, small mammalian herbivore, and large mammalian herbivore populations.	Are herbicide/insecticide residual concentrations on vegetation adversely affecting small avian herbivore, small mammalian herbivore, and large mammalian herbivore populations that may consume vegetation at the point of application and at a distance of 25 feet from the point of application?	Comparison of literature-derived acute and chronic toxicity endpoint values for survival, growth, and/or reproductive with modeled dietary exposure doses based on residual concentrations on vegetation.
Survival of small avian and small mammalian insectivore populations.	Are pesticide/herbicide residual concentrations on insects adversely affecting small avian and mammalian insectivore populations that may consume insects at the point of application?	Comparison of literature-derived acute toxicity endpoint values for survival with modeled dietary exposure doses based on residual concentrations on insects.
Survival of avian carnivore and mammalian carnivore populations.	Are pesticide/herbicide residual concentrations on small mammals (from direct spray) adversely affecting avian and mammalian carnivore populations that may be consuming small mammals at the point of application?	Comparison of literature-derived acute toxicity endpoint values for survival with modeled dietary exposure doses based on residual concentrations on small mammals.

TABLE 3-1
ASSESSMENT ENDPOINTS, RISK QUESTIONS, AND MEASUREMENT ENDPOINTS

Assessment Endpoint	Risk Questions	Measurement Endpoint
Terrestrial Habitat		
Survival, growth, and reproduction of benthic invertebrate communities.	Are herbicide/insecticide concentrations in an on-site pond following an accidental spill and herbicide/insecticide concentrations in an off-site pond receiving run-off and groundwater discharges from the point of application sufficient to adversely affect benthic invertebrate communities?	Comparison of chemical concentrations in surface water with acute toxicity endpoint values (on-site pond) and chronic toxicity endpoint values (off-site pond).
Survival, growth, and reproduction of fish communities.	Are herbicide/insecticide concentrations in an on-site pond following an accidental spill and herbicide/insecticide concentrations in an off-site pond receiving run-off and groundwater discharges from the point of application sufficient to adversely affect fish communities?	Comparison of chemical concentrations in surface water with acute toxicity endpoint values (on-site pond) and chronic toxicity endpoint values (off-site pond).
Survival, growth, and reproduction of amphibian communities.	Are herbicide/insecticide concentrations in an on-site pond following an accidental spill and herbicide/insecticide concentrations in an off-site pond receiving run-off and groundwater discharges from the point of application sufficient to adversely affect amphibian communities?	Comparison of chemical concentrations in surface water with acute toxicity endpoint values (on-site pond) and chronic toxicity endpoint values (off-site pond).
Survival, growth, and reproduction of phytoplankton and aquatic plant (macrophyte) communities.	Are herbicide/insecticide concentrations in an on-site pond following an accidental spill and herbicide/insecticide concentrations in an off-site pond receiving run-off and groundwater discharges from the point of application sufficient to adversely affect phytoplankton and aquatic plant communities?	Comparison of chemical concentrations in surface water with acute toxicity endpoint values (on-site pond) and chronic toxicity endpoint values (off-site pond).
Survival, growth, and reproduction of avian and mammalian piscivore populations.	Are herbicide/insecticide concentrations in an off-site pond receiving run-off and groundwater discharges from the point of application sufficient to adversely affect avian and mammalian piscivore populations that may consume fish from the pond?	Comparison of literature-derived chronic toxicity endpoint values for survival, growth, and/or reproductive effects with modeled dietary exposure doses based on herbicide/insecticide concentrations in surface water.

Source: Project Team

The population traits of interest for each of the assessment endpoints represent components of a healthy population. Failure or impairment of survival, growth, or reproduction will adversely affect the ability of the population to be healthy and viable and fill its appropriate role in an ecosystem. The assessment endpoints summarized in **Table 3-1** and in the previous bulleted lists do not apply to all of the active chemical ingredients evaluated by this ERA. As discussed in Section 3.1.1, certain potential

transport pathways (and therefore exposure pathways) are considered incomplete for Altosid XR, Pathfinder II, and Aquamaster (e.g., direct spray/spray drift deposition onto non-target biota and surface soil). Based on these incomplete pathways, many of the assessment endpoints established for terrestrial habitats, including survival of terrestrial invertebrate communities (pollinators), does not apply to Altosid XR, Pathfinder II, and Aquamaster. Assessment and measurement endpoints were not established for terrestrial plants since the majority of the chemicals used or planned for use produce adverse effects on a variety of terrestrial plant species by design.

3.2 ECOLOGICAL EFFECTS CHARACTERIZATION

The ecological effects characterization establishes the chemical exposure levels (i.e., toxicity reference values [TRVs]) that represent conservative thresholds for adverse ecological effects. A TRV is defined as a chemical concentration expressed as a media concentration (e.g., mg/L) or as an administered dose (e.g., mg/kg-body weight/day) that is used in conjunction with an exposure prediction to estimate ecological risk. As detailed in Section 3.3, acute (short-term) and/or chronic (long-term) exposure assessments were conducted for terrestrial wildlife (birds, mammals, and invertebrates) and aquatic organisms (fish, invertebrates, amphibians, and aquatic plants [algae and macrophytes]). As such, both acute and chronic TRVs were identified for each of the selected assessment endpoints. The specific literature sources accessed include:

- Fact sheets and literature from chemical manufactures;
- Information contained in risk assessments available from the USDA Forest Service, available at http://www.fs.fed.us/foresthealth/pesticide/risk.shtml;
- USEPA Integrated Risk Information System (IRIS) database (USEPA, 2005a), available at http://www.epa.gov/iriswebp/iris/index.html;
- Pesticide Action Network North America PAN Toxicity Database (Orme and Kegley, 2006), available at: http://www.pesticideinfo.org/Index.html;
- The Extension Toxicology Network (EXTOXNET) InfoBase available at http://extoxnet.orst.edu/;
- ECOTOX Database System, Aquatic Toxicity Information Retrieval (AQUIRE) (USEPA, 2005b), available at: http://www.epa.gov/ecotox/ecotox_home.htm;
- USEPA Ecotoxicity Database (USEPA, 2005c), described at: http://www.epa.gov/oppefed1/general/databasesdescription.htm - ecotoxicity;

- Federal Register environmental documents, available at http://www.epa.gov/fedrgstr/;
- Health Canada's Pest Management Regulatory Agency, available http://www.pmra-arla.gc.ca/english/index-e.html; and
- Re-registration Eligibility Decisions (REDs), available at http://cfpub.epa.gov/oppref/rereg/status.cfm?show=rereg.

The specific TRVs selected for those chemical-receptor combinations with potentially complete exposure pathways are summarized in **Table 3-2**. The TRVs presented are expressed as active ingredient (a.i.) or acid extractable (a.e.) concentrations or doses. Criteria used in their selection are presented and discussed in the sections that follow.

3.2.1 Fish, Amphibians, Aquatic Invertebrates, and Aquatic Plants

Test endpoints from standard acute toxicity tests (tests conducted over short periods of time, typically 48 hours for invertebrates and 96 hours for fish and amphibians) were used as acute TRVs for fish, amphibians, and aquatic invertebrates (**Table 3-2**). The types of effects that are measured in acute toxicity tests are typically lethality or sub-lethal effects (e.g., changes in behavior or immobilization) that illustrate adverse effects. The acute TRVs selected for fish, aquatic invertebrates, and amphibians are expressed as no observed effect levels (NOELs), no observed effect concentrations (NOECs), or no observed adverse effect levels (NOAELs). A NOEL or NOEC is defined as the highest concentration or amount of a substance that causes no detectable effect on survival or some other specifically quantified effect (e.g., immobility). A NOAEL is defined as the highest concentration of a chemical that causes no detectable adverse effect. Effects may be detected at this level; however, they are not judged to be adverse. When selecting acute TRVs, preference was given to NOEL and NOEC values. When more than one NOEL and/or NOEC was available for a given chemical-receptor combination, the minimum value was selected. In the absence of a NOEL or NOEC, the minimum NOAEL value was selected for use as the acute TRV.

For several chemical-receptor combinations involving aquatic invertebrates, fish, and/or amphibians, only median effective concentration (EC_{50}) or median lethal concentration (LC_{50}) values were identified from the literature. An EC_{50} is the concentration of test material that produces a specifically quantified effect to 50 percent of the test organisms, while an LC_{50} is the concentration of test material that is lethal to 50 percent of the exposed organisms. When only EC_{50} or LC_{50} values were available

from the literature, a NOEL/NOEC was established by applying a safety factor of 20 to the minimum EC_{50}/LC_{50} value. This safety factor is equivalent to the most conservative Level of Concern (LOC) or risk presumption used by the USEPA (2005d) to interpret acute risk estimates for aquatic life derived using LC_{50} values. **Table 3-2** presents acute TRVs for each chemical-receptor combination involving fish and aquatic invertebrates.

Chronic TRVs for fish, amphibians, and aquatic invertebrates were selected from the available toxicity data generated from tests that involved exposure over a longer time interval (e.g., toxicity tests conducted over the entire life cycle of the organism). The types of effects generally measured in chronic toxicity tests include reduced survival, growth, and/or reproduction. The chronic TRVs selected for fish, amphibians and aquatic invertebrates are expressed as NOELs or NOECs. For a given chemical-receptor combination, when more than NOEL or NOEC was available from the literature sources, the minimum value (i.e., most conservative value) was selected. In the absence of chronic toxicity data, a chronic TRV was established by applying a safety factor of 100 to the minimum acute NOEL/NOEC. In the absence of an experimental acute NOEL/NOEC value, the chronic TRV was established by applying a safety factor of 100 to the minimum EC_{50}/LC_{50} value identified from the literature (USEPA, 1997a). The USEPA (1997a) recommends a safety factor of 100 for estimating chronic TRVs from LC_{50} values.

In general, a distinction cannot be made between acute and chronic exposures for phytoplankton and macrophytes since toxicity data are not available for different exposure periods. Typical exposure durations encountered in the literature were 96 hours for phytoplankton and 14 days for macrophytes. Given the lack of toxicity data for different exposure periods, the same TRV was used for both acute and chronic exposures. The types of effects typically measured in toxicity tests with aquatic plants include population-based measures (i.e., changes in biomass, population growth rates, and abundance). For a given chemical-receptor combination, the TRVs established for aquatic plants are expressed as NOELs or NOECs. With the exception of methoprene and fenoxycarb, algae and macrophyte TRVs were identified from the literature for each chemical evaluated by this ERA.

TABLE 3-2
TOXICITY ENDPOINT VALUES

Receptor	Exposure Type	Test Organism	Test Duration	Effect	Endpoint	Toxicity Reference Value	Reference	Comments
Glyphosate - Isopropylamine Salt (Roundup Pro and Aquamaster)								
Honey bee	Acute	Honey bee (*Apis mellifera*)	48 hours	Survival	NOEL	1075 mg/kg	USDA, 2003a	LD_{50} reported as greater than 1075 mg/kg (NOEL assumed to be 1075 mg/kg); acute value is for technical grade glyphosate
Bird	Acute	Mallard duck (*Anas platyrhynchos*)	5 days	Survival	NOEC	562 mg/kg	USDA, 2003a	Value based on technical grade glyphosate
	Chronic	Mallard duck (*Anas platyrhynchos*)	One generation	Reproduction	NOEC	100 mg/kg/day	USDA, 2003a	Value based on technical grade glyphosate
Mammal	Acute	Rabbit	Days 6 - 27 of gestation	Maternal survival, systemic toxicity, and developmental effects in fetuses	NOAEL	175 mg/kg/day	USDA, 2003a	Value based on technical grade glyphosate
	Chronic	Rat	3 generations	Survival, systemic toxicity, and reproduction	NOAEL	30 mg/kg/day	USDA, 2003a	Value based on technical grade glyphosate
Fish	Acute	Bluegill sunfish (*Lepomis macrochirus*)	96 hours	Survival	NOEL	2.2 mg/L	USEPA, 2005c	Value based on technical grade glyphosate
	Chronic	---	---	---	NOEL	0.36 mg/L	USDA, 2003a	
Aquatic Invertebrate	Acute	Cladoceran (*Daphnia magna*)	48 hours	Survival	NOEL	1.9 mg/L	USEPA, 2005c	Value based on technical grade glyphosate
	Chronic	---	---	---	NOEL	0.7	USDA, 2003a	
Amphibian	Acute	---	---	---	NOEL	17.3 mg/L	---	Acute TRV estimated by applying a safety factor of 20 to the minimum LC_{50} value identified from the literature: 48-hour LC_{50} value for golden bell frog (Litoria moorei) reported by Mann and Bidwell, 1999 (343 mg/L; based on isopropylamine salt of glyphosate)
	Chronic	---	---	---	NOEL	3.43 mg/L	---	Chronic TRV estimated by applying a safety factor of 20 to the minimum LC_{50} value identified from the literature: 48-hour LC_{50} value for golden bell frog (Litoria moorei) reported by Mann and Bidwell, 1999 (343 mg/L; based on isopropylamine salt of glyphosate)
Algae	Acute	Green algae (*Scenedesmus quadricauda*)	96 hours	Population changes	NOEC	1.25 mg/L	Orme and Kegley, 2006	Value based on technical grade glyphosate
	Chronic	Green algae (*Scenedesmus quadricauda*)	96 hours	Population changes	NOEC	1.25 mg/L	Orme and Kegley, 2006	Value based on technical grade glyphosate
Macrophyte	Acute	Duckweed (*Lemna minor*)	Not specified	Number of fronds	NOEL	2.8 mg/L	USDA, 2003a	Value based on technical grade glyphosate
	Chronic	Duckweed (*Lemna minor*)	Not specified	Number of fronds	NOEL	2.8 mg/L	USDA, 2003a	Value based on technical grade glyphosate
Glyphosate - Potassium Salt (Roundup Original Max)								
Honey bee	Acute	Honey bee (*Apis mellifera*)	48 hours	Survival	NOEL	1075 mg/kg	USDA, 2003a	LD_{50} reported as greater than 1075 mg/kg (NOEL assumed to be 1075 mg/kg); acute value is for technical grade glyphosate
Bird	Acute	Mallard duck (*Anas platyrhynchos*)	5 days	Survival	NOEC	562 mg/kg	USDA, 2003a	Value based on technical grade glyphosate
	Chronic	Mallard duck (*Anas platyrhynchos*)	One generation	Reproduction	NOEC	100 mg/kg/day	USDA, 2003a	Value based on technical grade glyphosate
Mammal	Acute	Rabbit	Days 6 - 27 of gestation	Maternal survival, systemic toxicity, and developmental effects in fetuses	NOAEL	175 mg/kg/day	USDA, 2003a	Value based on technical grade glyphosate
	Chronic	Rat	3 generations	Survival, systemic toxicity, and reproduction	NOAEL	30 mg/kg/day	USDA, 2003a	Value based on technical grade glyphosate
Fish	Acute	Bluegill sunfish (*Lepomis macrochirus*)	96 hours	Survival	NOEL	2.2 mg/L	USEPA, 2005c	Value based on technical grade glyphosate
	Chronic	---	---	---	NOEL	0.36 mg/L	USDA, 2003a	
Aquatic Invertebrate	Acute	Cladoceran (*Daphnia magna*)	48 hours	Survival	NOEL	1.9 mg/L	USEPA, 2005c	Value based on technical grade glyphosate
	Chronic	---	---	---	NOEL	0.7	USDA, 2003a	
Amphibian	Acute	---	---	---	NOEL	4.06 mg/L	---	Acute TRV estimated by applying a safety factor of 20 to the minimum LC_{50} value identified from the literature: 48-hour LC_{50} value for golden bell frog (Litoria moorei) reported by Mann and Bidwell, 1999 (81.2 mg/L; based on technical grade glyphosate)

TABLE 3-2
TOXICITY ENDPOINT VALUES

Receptor	Exposure Type	Test Organism	Test Duration	Effect	Endpoint	Toxicity Reference Value	Reference	Comments
Amphibian – cont.	Chronic	---	---	---	NOEL	0.812 mg/L	---	Chronic TRV estimated by applying a safety factor of 20 to the minimum LC_{50} value identified from the literature: 48-hour LC_{50} value for golden bell frog (Litoria moorei) reported by Mann and Bidwell, 1999 (81.2 mg/L; based on technical grade glyphosate)
Algae	Acute	Green algae (*Scenedesmus quadricauda*)	96 hours	Population changes	NOEC	1.25 mg/L	Orme and Kegley, 2006	Value based on technical grade glyphosate
	Chronic	Green algae (*Scenedesmus quadricauda*)	96 hours	Population changes	NOEC	1.25 mg/L	Orme and Kegley, 2006	Value based on technical grade glyphosate
Macrophyte	Acute	Duckweed (*Lemna minor*)	Not specified	Number of fronds	NOEL	2.8 mg/L	USDA, 2003a	Value based on technical grade glyphosate
	Chronic	Duckweed (*Lemna minor*)	Not specified	Number of fronds	NOEL	2.8 mg/L	USDA, 2003a	Value based on technical grade glyphosate
Sulfometuron Methyl (Oust XP)								
Honey bee	Acute	Honey bee (*Apis mellifera*)	48 hours	Survival	NOEC	1,075 mg/kg	USDA, 2004a	
Bird	Acute	Mallard duck (*Anas platyrhynchos*)	9 days	Survival and weight gain	NOAEL	332.5 mg/kg/day	USDA, 2004a	
	Chronic	---	---	---	NOAEL	3.325 mg/kg/day	---	Chronic TRV estimated by applying a safety factor of 100 to the acute TRV: 9-day NOAEL for mallard duck (Anas platyrhynchos) reported by USDA, 2004a (332.5 mg/kg/day)
Mammal	Acute	Rat	10 days	Maternal and fetal weight gain	NOAEL	86.6 mg/kg/day	USDA, 2004a	
	Chronic	Rat	2 years	Hematological	NOAEL	2 mg/kg/day	USDA, 2004a	
Fish	Acute	Fathead minnow (*Pimephales promelas*)	96 hours	Survival	NOEC	7.3 mg/L	USDA, 2004a	
	Chronic	Fathead minnow (*Pimephales promelas*)	30 days	Embryo hatch, larval survival, and larval growth	NOEC	1.17 mg/L	USDA, 2004a	
Aquatic Invertebrate	Acute	Cladoceran (*Daphnia magna*)	48 hours	Survival	NOEC	12.5 mg/L	USDA, 2004a	
	Chronic	Cladoceran (*Daphnia magna*)	21 days	Reproduction	NOEC	6.1 mg/L	USEPA, 2005c	
Amphibian	Acute	African clawed frog (*Xenopus laevis*)	96 hours	Survival and malformations	NOEC	0.38 mg/L	USDA, 2004a	
	Chronic	African clawed frog (*Xenopus laevis*)	96 hours	Tail resorption rate	NOEC	0.00075 mg/L	USDA, 2004a	
Algae	Acute	Green algae (*Scenedesmus quadricauda*)	120 hours	Cell density	NOEC	0.0025 mg/L	USDA, 2004a	
	Chronic	Green algae (*Scenedesmus quadricauda*)	120 hours	Cell density	NOEC	0.0025 mg/L	USDA, 2004a	
Macrophyte	Acute	Duckweed (*Lemna gibba*)	14 days	Frond counts	NOEC	0.000207 mg/L	USEPA, 2005c	
	Chronic	Duckweed (*Lemna gibba*)	14 days	Frond counts	NOEC	0.000207 mg/L	USEPA, 2005c	
Sulfosulfuron (Outrider)								
Honey bee	Acute	Honey bee (*Apis mellifera*)	48 hours	Survival	NOEC	268.8 mg/kg	USEPA, 2005c	
Bird	Acute	Bobwhite quail (*Colinus virginianus*)	14 days	Survival	NOEL	810 mg/kg/day	USEPA, 2005c	
	Chronic	---	---	---	NOEL	8.1 mg/kg/day	---	Chronic TRV estimated by applying a safety factor of 100 to the acute TRV: 14-day LD_{50} for bobwhite quail (*Colinus virginianus*) reported by USEPA, 2005c (810 mg/kg/day)
Mammal	Acute	Rat	4 weeks	Systemic toxicity	NOEL	668.74 mg/kg/day	Health Canada, 1998	
	Chronic	Rat	2 years	Urolithrasis and pathological findings	NOEL	24.4 mg/kg/day	Health Canada, 1998	
Fish	Acute	Rainbow trout (*Oncornhynchus mykiss*)	96 hours	Survival	NOEL	95 mg/L	USEPA, 2005c	
	Chronic	Rainbow trout (*Oncornhynchus mykiss*)	32 days	Growth	NOEL	100 mg/L	USEPA, 2005c	
Aquatic Invertebrate	Acute	Cladoceran (*Daphnia magna*)	48 hours	Survival	NOEL	96 mg/L	USEPA, 2005c	
	Chronic	Cladoceran (*Daphnia magna*)	21 days	Survival, growth, and reproduction	NOEL	102 mg/L	USEPA, 2005c	

TABLE 3-2
TOXICITY ENDPOINT VALUES

Receptor	Exposure Type	Test Organism	Test Duration	Effect	Endpoint	Toxicity Reference Value	Reference	Comments
Amphibian	Acute	---	---	---	---	No data	---	No data identified from the literature
	Chronic	---	---	---	---	No data	---	No data identified from the literature
Algae	Acute	Green algae (*Scenedesmus quadricauda*)	120 hours	Abundance	NOEL	0.188 mg/L	USEPA, 2005c	
	Chronic	Green algae (*Scenedesmus quadricauda*)	120 hours	Abundance	NOEL	0.188 mg/L	USEPA, 2005c	
Macrophyte	Acute	Duckweed (*Lemna gibba*)	14 days	Abundance	NOEL	0.0005 mg/L	USEPA, 2005c	
	Chronic	Duckweed (*Lemna gibba*)	14 days	Abundance	NOEL	0.0005 mg/L	USEPA, 2005c	
Metsulfuron Methyl (Escort XP)								
Honey bee	Acute	Honey bee (*Apis mellifera*)	48 hours	Survival	NOEL	268.8 mg/kg	USEPA, 2005c	
Bird	Acute	Bobwhite quail (*Colinus virginianus*)	5 days	Survival	NOEL	1043 mg/kg/day	USDA, 2004b	
	Chronic	Mallard duck (*Anas platyrhynchos*)	24 weeks	Survival, weight gain, food consumption, and reproduction	NOEL	120 mg/kg/day	USDA, 2004b	
Mammal	Acute	Rat	90 days	Survival	NOEL	521 mg/kg/day	USDA, 2004b	
	Chronic	Rat	52 weeks	Weight gain	NOEL	25 mg/kg/day	USDA, 2004b	
Fish	Acute	Rainbow trout (*Oncornhynchus mykiss*)	96 hours	Survival	NOAEL	10 mg/L	USDA, 2004b	
	Chronic	Rainbow trout (*Oncornhynchus mykiss*)	90 days	First day of hatching and length of surviving fingerlings	NOEC	4.5 mg/L	USEPA, 2005c	
Aquatic Invertebrate	Acute	Cladoceran (*Daphnia magna*)	48 hours	Survival	NOEC	150 mg/L	USDA, 2004b	
	Chronic	Cladoceran (*Daphnia magna*)	21 days	Growth	NOEC	17 mg/L	USDA, 2004b	
Amphibian	Acute	---	---	---	---	---	---	No data identified from the literature
	Chronic	---	---	---	---	---	---	No data identified from the literature
Algae	Acute	Green algae (*Selenastrum capricornutum*)	120 hours	Cell inhibition	NOEL	0.01 mg/L	USEPA, 2005c	
	Chronic	Green algae (*Selenastrum capricornutum*)	120 hours	Cell inhibition	NOEL	0.01 mg/L	USEPA, 2005c	
Macrophyte	Acute	Duckweed (*Lemna minor*)	14 days	Frond chlorosis and blackening	NOEL	0.00016 mg/L	USEPA, 2005c	
	Chronic	Duckweed (*Lemna minor*)	14 days	Frond chlorosis and blackening	NOEL	0.00016 mg/L	USEPA, 2005c	
Fluroxypyr - Fluroxypyr 1-Methylheptyl Ester (Vista)								
Honey bee	Acute	Honey bee (*Apis mellifera*)	48 hours	Survival	NOEL	268.8 mg/kg	USEPA, 2005c	
Bird	Acute	---	---	---	NOEC	200 mg/kg/day	---	Acute TRV estimated by applying a safety factor of 10 to the minimum LD50 value identified from the literature: 14-day LD50 for bobwhite quail (Colinus virginianus) reported by USEPA, 2005c (2000 mg/kg)
	Chronic	---	---	---	NOEC	20 mg/kg	---	Chronic TRV estimated by applying a safety factor of 100 to the minimum LD50 value identified from the literature: 14-day LD50 for bobwhite quail (Colinus virginianus) reported by USEPA, 2005c (2000 mg/kg/day)
Mammal	Acute	Rat	Days 6 - 15 of gestation	Maternal weight gain, food consumption, systemic toxicity, and developmental toxicity in fetuses	NOEL	300 mg/kg/day	FR 68(10):2027-2032	
	Chronic	Rat	90 days	Not specified	NOEL	80 mg/kg/day	FR 68(10):2027-2032	
Fish	Acute	Bluegill sunfish (*Lepomis macrochirus*)	96 hours	Survival	NOEL	0.63 mg/L	USEPA, 2005c	
	Chronic	---	---	---	NOEL	0.0063 mg/L	---	Chronic TRV estimated by applying a safety factor of 100 to the acute TRV: 96-hour NOEL for bluegill sunfish (Lepomis macrochirus) reported by USEPA, 2005c (0.63 mg/L)

TABLE 3-2
TOXICITY ENDPOINT VALUES

Receptor	Exposure Type	Test Organism	Test Duration	Effect	Endpoint	Toxicity Reference Value	Reference	Comments
Aquatic Invertebrate	Acute	Daggerblade grass shrimp (*Palaemonetes pugio*)	96 hours	Not specified	NOEL	0.135 mg/L	USEPA, 2005c	No freshwater values for ester formulation; acute value is for a saltwater species
	Chronic	Cladoceran (*Daphnia magna*)	21 days	Survival, growth, and reproduction	NOEL	0.06 mg/L	USEPA, 2005c	
Amphibian	Acute	---	---	---	---	---	---	No data identified from the literature
	Chronic	---	---	---	---	---	---	No data identified from the literature
Algae	Acute	blue-green algae (*Anabaena flos-aquae*)	120 hours	Abundance	NOEL	0.03 mg/L	USEPA, 2005c	
	Chronic	blue-green algae (*Anabaena flos-aquae*)	120 hours	Abundance	NOEL	0.03 mg/L	USEPA, 2005c	
Macrophyte	Acute	Duckweed (*Lemna gibba*)	14 days	Not specified	NOEL	0.437 mg/L	USEPA, 2005c	
	Chronic	Duckweed (*Lemna gibba*)	14 days	Not specified	NOEL	0.437 mg/L	USEPA, 2005c	
Triclopyr BEE (Pathfinder II)								
Honey bee	Acute	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Acute exposure pathway incomplete for terrestrial pollinators
Bird	Acute	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Acute exposure pathway incomplete for terrestrial birds; acute scenario for semi-aquatic birds was not evaluated
	Chronic	Mallard duck (*Anas platyrhynchos*)	1 generation	Survival, body weight gain, food consumption, and reproduction	NOAEL	10 mg/kg/day	USDA, 2003b	Value based on technical grade triclopyr
Mammal	Acute	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Acute exposure pathway incomplete for terrestrial mammals; acute scenario for semi-aquatic mammals was not evaluated
	Chronic	Rat	Two generations	Body weight, food consumption, histopathological changes in liver and kidney, and reproduction	NOAEL	5 mg/kg/day	USDA, 2003b	Value based on technical grade triclopyr
Fish	Acute	Bluegill sunfish (*Lepomis macrochirus*)	96 hours	Survival	NOEL	0.2 mg/L	USEPA, 2005c	
	Chronic	Rainbow trout (*Oncornhynchus mykiss*)	65 days	Egg hatchability and fingerling survival and growth	NOEL	0.026 mg/L	USEPA, 2005c	
Aquatic Invertebrate	Acute	Cladoceran (*Daphnia magna*)	48 hours	Survival	NOEL	0.27 mg/L	USEPA, 2005c	
	Chronic	---	---	---	NOEL	0.00027 mg/L	---	Chronic TRV estimated by applying a safety factor of 100 to the acute TRV: 48-hour NOEL for *Daphnia magna* (cladoceran) reported by USEPA, 2005c (0.27 mg/L)
Amphibian	Acute	---	---	---	---	---	---	No data identified from the literature
	Chronic	---	---	---	---	---	---	No data identified from the literature
Algae	Acute	Diatom (*Navicula pelliculosa*)	24 hours	Abundance	NOEL	0.002 mg/L	USEPA, 2005c	
	Chronic	Diatom (*Navicula pelliculosa*)	24 hours	Abundance	NOEL	0.002 mg/L	USEPA, 2005c	
Macrophyte	Acute	Duckweed (*Lemna gibba*)	Not reported	Number of fronds	NOEC	3 mg/L	USDA, 2003b	Value based on technical grade triclopyr
	Chronic	Duckweed (*Lemna gibba*)	Not reported	Number of fronds	NOEC	3 mg/L	USDA, 2003b	Value based on technical grade triclopyr
Triclopyr TEA (Garlon 3a)								
Honey bee	Acute	Honey bee (*Apis mellifera*)	48 hours	Survival	NOEL	1075 mg/kg	USEPA, 2005c	
Bird	Acute	---	---	---	NOEL	73.5 mg/kg	---	Acute TRV estimated by applying a safety factor of 10 to the minimum LD_{50} value identified from the literature: 21-day LD_{50} for bobwhite quail (*Colinus virginianus*) reported by USEPA, 2005c (735 mg/kg; value for triclopyr BEE)
	Chronic	Mallard duck (*Anas platyrhynchos*)	1 generation	Survival, body weight gain, food consumption, and reproduction	NOAEL	10 mg/kg/day	USDA, 2003b	Value based on technical grade triclopyr

TABLE 3-2
TOXICITY ENDPOINT VALUES

Receptor	Exposure Type	Test Organism	Test Duration	Effect	Endpoint	Toxicity Reference Value	Reference	Comments
Mammal	Acute	New Zealand white rabbit	Days 6 - 18 of gestation	Survival, body weight, food consumption, and reproduction	NOAEL	30 mg/kg	USDA, 2003b	Value based on triclopyr BEE
	Chronic	Rat	Two generations	Body weight, food consumption, histopathological changes in liver and kidney, and reproduction	NOAEL	5 mg/kg/day	USDA, 2003b	Value based on technical grade triclopyr
Fish	Acute	Fathead minnow (*Pimephales promelas*)	96 hours	Survival	NOEL	98 mg/L	USEPA, 2005c	
	Chronic	Fathead minnow (*Pimephales promelas*)	28 days	Survival and reproduction	NOEL	104 mg/L	USEPA, 2005c	
Aquatic Invertebrate	Acute	Cladoceran (*Daphnia magna*)	21 days	Survival and reproduction	NOEC	80.7 mg/L	USDA, 2003b	Chronic TRV used as acute TRV (a safety factor of 20 applied to minimum EC_{50}/LC_{50} value (132 mg/L) would result in an estimated acute NOEC that is less than the experimental chronic NOEL value of 80.7 mg/L
	Chronic	Cladoceran (*Daphnia magna*)	21 days	Survival and reproduction	NOEC	80.7 mg/L	USDA, 2003b	
Amphibian	Acute	---	---	---	---	---	---	No data identified from the literature
	Chronic	---	---	---	---	---	---	No data identified from the literature
Algae	Acute	blue-green algae (*Anabaena flos-aquae*)	7 days	Abundance	NOEL	2 mg/L	USEPA, 2005c	
	Chronic	blue-green algae (*Anabaena flos-aquae*)	7 days	Abundance	NOEL	2 mg/L	USEPA, 2005c	
Macrophyte	Acute	Duckweed (*Lemna gibba*)	14 days	Abundance	NOEL	7.8 mg/L	USEPA, 2005c	
	Chronic	Duckweed (*Lemna gibba*)	14 days	Abundance	NOEL	7.8 mg/L	USEPA, 2005c	
Clopyralid - Monoethanolamine Salt Formulation (Transline)								
Honey bee	Acute	Honey bee (*Apis mellifera*)	48 hours	Survival	NOEL	1075 mg/kg	USEPA, 2005c	
Bird	Acute	Mallard duck (*Anas platyrhynchos*)	14 days	Survival	NOEL	631 mg/kg	USEPA, 2005c	
	Chronic	Mallard duck (*Anas platyrhynchos*)	Not applicable	No chronic toxicity data	NOEL	6.31 mg/kg/day	Not applicable	Chronic TRV estimated by applying a safety factor of 100 to the acute TRV: 14-day NOEL for mallard duck (*Anas platyrhynchos*) reported by USEPA, 2005c (631 mg/kg)
Mammal	Acute	Rat	Days 6 -15 of gestation	Maternal weight gain, food and water consumption, and malformations in young	NOAEL	75 mg/kg/day	USDA, 2004c	
	Chronic	Rat	2 years	Liver and kidney pathology, clinical chemistry, and other systemic effects	NOAEL	15 mg/kg/day	USDA, 2004c	
Fish	Acute	Rainbow trout (*Oncornhynchus mykiss*)	96 hours	Survival	NOEC	80 mg/L	USEPA, 2005c	
	Chronic	Rainbow trout (*Oncornhynchus mykiss*)	21 days	Survival	NOEC	43.8 mg/L	USDA, 2004c	
Aquatic Invertebrate	Acute	Cladoceran (*Daphnia magna*)	48 hours	Survival	NOEL	100 mg/L	USEPA, 2005c	
	Chronic	Cladoceran (*Daphnia magna*)	Not specified	Reproduction	NOEC	23.1 mg/L	USDA, 2004c	
Amphibian	Acute	Fowler's toad (*Bufo fowleri*)	96 hours	Survival	NOEC	151 mg/L	USDA, 2004c	
	Chronic	---	---	---	NOEC	1.51 mg/L	---	Chronic TRV estimated by applying a safety factor of 100 to the acute TRV: 96-hour NOEL for Fowler's toad (*Bufo fowleri*) reported by USDA, 2004c (151 mg/L)
Algae	Acute	Blue-green algae (*Anabaena flos-aquae*)	5 days	Growth inhibition (cell counts)	NOEC	24.2 mg/L	KTTK, 2005	Lower value available from literature (EC_{50} = 6.7 mg/L; Dill and Milazzo, 1985)); however, data was not used based on several deficiencies associated with study (see KTTK, 2005)
	Chronic	---	---	---	NOEC	24.2 mg/L	KTTK, 2005	
Macrophyte	Acute	Duckweed (*Lemna gibba*)	14 days	Not reported	NOEC	7.2 mg/L	Dow AgroSciences, 1998	
	Chronic	---	---	---	NOEC	7.2 mg/L	Dow AgroSciences, 1998	

TABLE 3-2
TOXICITY ENDPOINT VALUES

Receptor	Exposure Type	Test Organism	Test Duration	Effect	Endpoint	Toxicity Reference Value	Reference	Comments
Methoprene (Briquet - Altsoid XR)								
Honey bee	Acute	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Acute exposure pathway incomplete for terrestrial pollinators
Bird	Acute	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Acute exposure pathway incomplete for terrestrial birds; acute scenario for semi-aquatic birds was not evaluated
	Chronic	---	---	---	NOEL	5 mg/kg/day	---	Chronic TRV estimated by applying a safety factor of 100 to the minimum acute NOEL identified from the literature: 14-day NOEL for bobwhite quail reported by EXTOXNET, 2005d (500 mg/kg)
Mammal	Acute	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Acute exposure pathway incomplete for terrestrial mammals; acute scenario for semi-aquatic mammals was not evaluated
	Chronic	Mouse	2 years	Survival, systemic toxicity, and reproduction	NOAEL	30 mg/kg/day	EXTOXNET, 1996	
Fish	Acute	---	---	---	NOEL	0.051 mg/L	---	Acute TRV estimated by applying a safety factor of 20 to the minimum LC_{50} value identified from the literature: 96-hour LC_{50} for rainbow trout reported by USEPA, 2005c (1.01 mg/L)
	Chronic	Fathead minnow (*Pimephales promelas*)	37 days	Growth	NOEC	0.048 mg/L	USEPA, 2005c	
Aquatic Invertebrate	Acute	Cladoceran (*Daphnia magna*)	42 days	Survival, growth, and reproduction	NOEL	0.027 mg/L	USEPA, 2005c	Chronic TRV used as acute TRV (a safety factor of 20 applied to minimum EC_{50}/LC_{50} value (0.071 mg/L) would result in an estimated acute NOEL that is less than the experimental chronic NOEL value of 0.027 mg/L
	Chronic	Cladoceran (*Daphnia magna*)	42 days	Survival, growth, and reproduction	NOEL	0.027 mg/L	USEPA, 2005c	
Amphibian	Acute	Northern leopard frog (*Rana pipiens*)	Not specified	Developmental effects	NOEC	0.4 mg/L	USEPA, 2005c	
	Chronic	Northern leopard frog (*Rana pipiens*)	Not specified	Developmental effects	NOEC	0.4 mg/L	USEPA, 2005c	
Algae	Acute	---	---	---	---	---	---	No data identified from the literature
	Chronic	---	---	---	---	---	---	No data identified from the literature
Macrophyte	Acute	---	---	---	---	---	---	No data identified from the literature
	Chronic	---	---	---	---	---	---	No data identified from the literature
Chlorsulfuron (Landmark MP)								
Honey bee	Acute	Honey bee (*Apis mellifera*)	48 hours	Survival	NOEC	268.8 mg/kg	USDA, 2004d	LD_{50} reported as greater than 268.8 mg/kg; NOEC assumed to be 268.8 mg/kg
Bird	Acute	Bobwhite quail (*Colinus virginianus*)	14 days	Survival	NOEC	1686 mg/kg/day	USDA, 2004d	
	Chronic	Mallard duck (*Anas platyrhynchos*)	20 weeks	Survival, body weight, food consumption, and reproduction	NOEC	140 mg/kg/day	USDA, 2004d	
Mammal	Acute	Rat	days 7 - 19 of gestation	Maternal weight gain, food consumption, and clinical toxicity and fetal survival	NOAEL	165 mg/kg/day	USDA, 2004d	
	Chronic	Rat	2 years (3 generations)	Hematological, other clinical chemistry endpoints, and body weight	NOAEL	5 mg/kg/day	USDA, 2004d	
Fish	Acute	Brown trout (*Salmo trutta*)	96 hours	Survival	NOEC	30 mg/L	USDA, 2004d	
	Chronic	Rainbow trout (*Oncornhynchus mykiss*)	77 days	Embryo and fingerling survival and length of surviving fish	NOEC	32 mg/L	USDA, 2004d	
Aquatic Invertebrate	Acute	Cladoceran (*Daphnia magna*)	48 hours	Survival	NOEC	10 mg/L	USDA, 2004d	
	Chronic	Cladoceran (*Daphnia magna*)	21 days	Survival, growth, and reproduction	NOEC	20 mg/L	USEPA, 2005c	
Amphibian	Acute	---	---	---	---	No data available	---	No data identified from the literature
	Chronic	---	---	---	---	No data available	---	No data identified from the literature

TABLE 3-2
TOXICITY ENDPOINT VALUES

Receptor	Exposure Type	Test Organism	Test Duration	Effect	Endpoint	Toxicity Reference Value	Reference	Comments
Algae	Acute	Green algae (*Scenedesmus quadricauda*)	120 hours	Cell counts	NOEC	0.0094 mg/L	USEPA, 2005c	
	Chronic	Green algae (*Scenedesmus quadricauda*)	120 hours	Cell counts	NOEC	0.0094 mg/L	USEPA, 2005c	
Macrophyte	Acute	Duckweed (*Lemna gibba*)	14 days	Number of fronds	NOEC	0.00024 mg/L	USEPA, 2005c	
	Chronic	Duckweed (*Lemna gibba*)	14 days	Number of fronds	NOEC	0.00024 mg/L	USEPA, 2005c	
Amino Pyralid (Milestone VM)								
Honey bee	Acute	Honey bee (*Apis mellifera*)	48 hours	Survival	NOEC	1075 mg/kg	USEPA, 2005e	LD_{50} reported as greater than 1075 mg/kg; NOEC assumed to be 1075 mg/kg
Bird	Acute	Bobwhite quail (*Colinus virginianus*)	Not specified	Survival	NOEC	2250 mg/kg	USEPA, 2005e	LD_{50} reported as greater than 2,250 mg/kg; NOEC assumed to be 2250 mg/kg
	Chronic	---	---	---	NOEC	22.5 mg/kg/day	---	Chronic TRV estimated by applying a safety factor of 100 to the minimum LD_{50} value identified from the literature: LD_{50} for bobwhite quail (*Colinus virginianus*) reported by USEPA, 2005d (>2250 mg/kg)
Mammal	Acute	Rabbit	Days 7 - 10 of gestation	Maternal food consumption and histopathology	NOAEL	104 mg/kg/day	USEPA, 2005e	
	Chronic	Rat	2 years	Body weight and stomach histopathology	NOAEL	50 mg/kg/day	USEPA, 2005e	
Fish	Acute	Rainbow trout (*Oncornhynchus mykiss*)	96 hours	Survival	NOEC	100 mg/L	USEPA, 2005e	LC_{50} reported as greater than 100 mg/L; NOEC assumed to be 100 mg/L
	Chronic	Fathead minnow (*Pimephales promelas*)	Not specified	Not specified	NOEC	1.36 mg/L	USEPA, 2005e	
Aquatic Invertebrate	Acute	Cladoceran (*Daphnia magna*)	48 hours	Survival	NOEC	98.6 mg/L	USEPA, 2005e	EC_{50} reported as greater than 100 mg/L; NOEC assumed to be 100 mg/L
	Chronic	Cladoceran (*Daphnia magna*)	Not specified	Growth and reproduction	NOEC	102 mg/L	USEPA, 2005e	
Amphibian	Acute	Northern leopard frog (*Rana pipiens*)	96 hours	Survival	NOEC	95.2 mg/L	USEPA, 2005e	EC_{50} reported as greater than 95.2 mg/L; NOEC assumed to be 95.2 mg/L
	Chronic	---	---	---	NOEC	0.952 mg/L	USEPA, 2005e	Chronic TRV estimated by applying a safety factor of 100 to the minimum LC_{50}/EC_{50} value reported from the literature: 96-hour EC_{50} for northern leopard frog (*Rana pipiens*) reported by USEPA, 2005d (>95.2 mg/L).
Algae	Acute	Diatom (*Navicula pelliculosa*)	96 hours	Not specified	NOEC	6 mg/L	USEPA, 2005e	
	Chronic	---	---	---	NOEC	6 mg/L	USEPA, 2005e	
Macrophyte	Acute	Duckweed (*Lemna gibba*)	14 days	Not specified	NOEC	44 mg/L	USEPA, 2005e	
	Chronic	---	---	---	NOEC	44 mg/L	USEPA, 2005e	
Imazapyr (Habitat)								
Honey bee	Acute	Honey bee (*Apis mellifera*)	48 hours	Survival	NOEC	1075 mg/kg (see comments)	USEPA, 2005c	LD_{50} reported as >1075 mg/kg by USEPA, 2005c; NOEC assumed to be 1075 mg/kg
Bird	Acute	Bobwhite quail (*Colinus virginianus*)	5 days	Survival	NOEC	674 mg/kg/day	USDA, 2004e	
	Chronic	Bobwhite quail (*Colinus virginianus*)	18 weeks	Egg production, hatchability, and hatchling survival	NOEC	200 mg/kg/day	USDA, 2004e	
Mammal	Acute	Rat	13 weeks	Weight gain, food consumption, gross pathology, organ weights, histopathology, and other systemic effects	NOAEL	1695 mg/kg/day	USDA, 2004e	
	Chronic	Dog (beagle)	1 year	Survival and clinical toxicity	NOAEL	262.9 mg/kg/day	USDA, 2004e	
Fish	Acute	Rainbow trout (*Oncornhynchus mykiss*)	96 hours	Survival	NOEL	100 mg/L	USEPA, 2005c	
	Chronic	Rainbow trout (*Oncornhynchus mykiss*)	28 days	Hatching and fingling survival and growth	NOEL	43.1 mg/kg	USEPA, 2005c	
Aquatic Invertebrate	Acute	Cladoceran (*Daphnia magna*)	48 hours	Survival	NOEC	100 mg/kg	USDA, 2004e	
	Chronic	Cladoceran (*Daphnia magna*)	21 days	Survival, growth, and reproduction	NOEL	97.1 mg/L	USEPA, 2005c	

TABLE 3-2
TOXICITY ENDPOINT VALUES

Receptor	Exposure Type	Test Organism	Test Duration	Effect	Endpoint	Toxicity Reference Value	Reference	Comments
Amphibian	Acute	---	---	---	---	---	---	No data identified from the literature
	Chronic	---	---	---	---	---	---	No data identified from the literature
Algae	Acute	Blue-green algae (*Anabaena flos-aquae*)	7 days	Cell counts	NOEL	9.6 mg/L	USEPA, 2005c	
	Chronic	Blue-green algae (*Anabaena flos-aquae*)	7 days	Cell counts	NOEL	9.6 mg/L	USEPA, 2005c	
Macrophyte	Acute	Duckweed (*Lemna gibba*)	14 days	Frond counts	NOEL	0.01 mg/L	USEPA, 2005c	
	Chronic	Duckweed (*Lemna gibba*)	14 days	Frond counts	NOEL	0.01 mg/L	USEPA, 2005c	
Fenoxycarb (Award)								
Honey bee	Acute	Honey bee (*Apis mellifera*)	48 hours	Survival	NOEL	1075 mg/kg	EXTOXNET, 1993	LD_{50} reported as greater than 1075 mg/kg by EXTOXNET, 1993; NOEL assumed to be 1075 mg/kg
Bird	Acute	---	---	---	NOEL	300 mg/kg/day	---	Acute TRV estimated by applying a safety factor of 10 to the minimum LD_{50} value identified from the literature: 14-day LD_{50} for bobwhite quail (*Colinus virginianus*) reported by USEPA, 2005c (3000 mg/kg)
	Chronic	---	---	---	NOEL	30 mg/kg/day	---	Chronic TRV estimated by applying a safety factor of 100 to the minimum LD_{50} value identified from the literature: 14-day LD_{50} for bobwhite quail (*Colinus virginianus*) reported by USEPA, 2005c (3000 mg/kg)
Mammal	Acute	---	---	---	NOEL	50 mg/kg/day	---	Acute TRV estimated by applying a safety factor of 10 to the minimum LD_{50} value identified from the literature: LD_{50} for rat reported in FR Vol 62 (80):20111-20117 (500 mg/kg/day)
	Chronic	Rat	2 years	Liver toxicity	NOEL	8.1 mg/kg/day	FR Vol 62 (80):20111-20117	
Fish	Acute	Rainbow trout (*Oncornhynchus mykiss*)	96 hours	Survival	NOEL	0.5 mg/L	USEPA, 2005c	
	Chronic	Rainbow trout (*Oncornhynchus mykiss*)	74 days	Growth	NOEL	0.048 mg/L	USEPA, 2005c	
Aquatic Invertebrate	Acute	Cladoceran (*Daphnia magna*)	48 hours	Survival	NOEL	0.05 mg/L	USEPA, 2005c	
	Chronic	Cladoceran (*Daphnia magna*)	21 days	Growth and reproduction	NOEL	0.0000016 mg/L	USEPA, 2005c	
Amphibian	Acute	---	---	---	---	---	---	No data identified from the literature
	Chronic	---	---	---	---	---	---	No data identified from the literature
Algae	Acute	---	---	---	---	---	---	No data identified from the literature
	Chronic	---	---	---	---	---	---	No data identified from the literature
Macrophyte	Acute	---	---	---	---	---	---	No data identified from the literature
	Chronic	---	---	---	---	---	---	No data identified from the literature

Notes:

LC_{50} = Median Lethal Concentration
LD_{50} = Median lethal Dose
EC_{50} = Median Effective Concentration
EXTOXNET = Extension Toxicity Network
FR = Federal Register
BEE = Butoxyethyl Ester
TEA = Triethylamine Salt
TRV = Toxicity Reference Value
NOEC = No Observed Effect Concentration
NOEL = No Observed Effect Level
NOAEL = No Observed Adverse Effect Level
USEPA = Unites States Environmental Protection Agency
USDA = United States Department of Agriculture
mg/L = milligram per liter
mg/kg = milligram per kilogram - body weight
mg/kg/day = milligram per kilogram - body weight per day

Source: Project Team

3.2.2 Birds, Mammals, and Invertebrates

A standard contact toxicity test using honeybees is required by the USEPA for pesticide registration. Available data from these acute tests (NOELs/NOECs based on survival) were used as acute TRVs for this receptor.

Test endpoints for short-term feeding studies, multiple dose gavage studies, or single-dose gavage studies were used as acute TRVs for birds and mammals. The effects generally measured in these tests are survival or sub-lethal effects (e.g., decreased food consumption and weight gain) that illustrate adverse effects. When toxicity test data were available for both short-term feeding studies and gavage studies, preference was given to data from feeding studies since they represent more realistic exposures to chemicals in the wild. The acute toxicity values selected for birds and mammals are expressed as NOECs, NOELs, or NOAELs (**Table 3-2**). When selecting acute TRVs, preference was given to NOEL and NOEC values. When more than one NOEL and/or NOEC was available for a given chemical-receptor combination, the minimum value was selected. In the absence of a NOEL or NOEC, the minimum NOAEL value was selected for use as the acute TRV. For several chemical-receptor combinations involving birds and/or mammals, only median lethal dose (LD_{50}) values were identified from the literature. An LD_{50} is the dose of test material that is lethal to 50 percent of the exposed organisms. When only LD_{50} values were available from the literature, the acute NOEL/NOEC was estimated by applying a safety factor of 10 to the minimum LD_{50} value. This safety factor is equivalent to the most conservative LOC used by the USEPA (2005d) to interpret acute risk estimates for birds and mammals.

Test endpoints from chronic feeding studies conducted over longer time periods (typically 20 weeks for birds and 2 years for mammals) were used as chronic TRVs. Effects measured in chronic tests include lethal effects and sub-lethal effects (e.g., reproductive impairment, histopathology, cellular changes, and physiological changes). Specific endpoints selected as chronic TRVs are expressed as NOELs, NOECs, and NOAELs. In the absence of a chronic toxicity data expressed as a dose, the chronic TRV was estimated by applying a safety factor of 100 to the minimum acute NOEL/NOEC value. In the absence of an experimental acute NOEL/NOEC value, the chronic TRV was estimated by applying a safety factor of 100 to the minimum LD_{50} value identified from the literature. The USEPA (1997a) recommends a safety factor of 100 for estimating chronic NOELs/NOECs from LD_{50} values.

3.3 EXPOSURE CHARACTERIZATION

The exposure characterization evaluates the duration and intensity of exposure. Intensity refers to the amount of a chemical contacted per day, while duration refers to the time over which exposure occurs (USEPA, 1998a). The sections that follow present the various scenarios selected to evaluate potential exposures by ecological receptors to the various active ingredients present in formulations used by TxDOT in its Roadside Pest Management Program.

3.3.1 Terrestrial Wildlife

In determining the level of exposure for birds and mammals, two time scales were considered: 1) short-term (acute) exposures representing relatively high levels of exposure over a short period of time (i.e., 24-hour exposure period beginning shortly after application); and 2) long-term (chronic) exposures representing low levels of exposure over an extended period of time (i.e., 90-day exposure period beginning shortly after application).

For purposes of this report, a reasonable number of exposure scenarios were considered. The exclusion of a given chemical from evaluation by a particular scenario is based on the conceptual model discussed in Section 3.1.1.

Acute (short-term) exposure scenarios include:

- Direct spray of a small bird and small mammal during application of chemical (all herbicides/insecticides except Altosid XR, Pathfinder II, and Aquamaster);
- Ingestion of contaminated food items at the point of application by an on-site small avian herbivore, small avian insectivore, avian carnivore, small mammalian herbivore, large mammal herbivore, small mammalian insectivore, and mammalian carnivore for a period of 24 hours beginning shortly after application of the chemical (all herbicides/insecticides except Altosid XR, Pathfinder II, and Aquamaster); and
- Ingestion of contaminated surface water from an on-site pond by a small bird and small mammal for a period of 24 hours beginning shortly after an accidental spill (all herbicides/insecticides except Altosid XR).

Chronic (long-term) exposure scenarios include:

- Ingestion of contaminated vegetation at the point of application by a small avian herbivore, small mammalian herbivore, and large mammalian herbivore for a period of 90 days beginning shortly after application of the chemical (all herbicides/insecticides except Altosid XR, pathfinder II, and Aquamaster);
- Ingestion of contaminated vegetation at a distance of 25 feet from the point of application by a small avian herbivore, small mammalian herbivore, and large mammalian herbivore for a period of ninety days beginning shortly after application of the chemical (all herbicides/insecticides except Altosid XR, Pathfinder II, and Aquamaster);
- Ingestion of contaminated fish from an off-site pond by an avian piscivore and mammalian piscivore for a period of 90 days (all chemicals except Pathfinder II); and
- Ingestion of contaminated surface water from an off-site pond by a small bird and small mammal for a period of 90 days (all herbicides/insecticides except Pathfinder II).

Given the statewide applicability of the program and the resulting large number of potential receptors, "generic birds and mammals" were selected as surrogates for specific species (USEPA, 1999 and 2005d) in this ERA. Generic birds and mammals were assigned a defined body size (i.e., weight) and food type, making them representative of four primary feeding groups (herbivores, insectivores, carnivores, and piscivores). The hypothetical avian and mammalian receptors selected, as well as their assigned body weights are listed in **Table 3-3**.

TABLE 3-3
HYPOTHETICAL GENERIC BIRDS AND MAMMALS

Hypothetical Receptor	Body Weight
Small avian herbivore (granivore)	0.01 kg
Small avian insectivore	0.01 kg
Avian carnivore	0.5 kg
Avian piscivore	0.3 kg
Small mammalian herbivore (granivore)	0.02 kg
Small mammalian insectivore	0.02 kg
Large mammalian herbivore	70 kg
Mammalian carnivore	5.0 kg
Mammalian piscivore	0.75 kg

Source: Project Team

Based on body weights and life history information provided by the Cornell Lab of Ornithology (2003; available at http://www.birds.cornell.edu/programs/AllAboutBirds/BirdGuide/), the on-line version of the Mammals of Texas (Davis and Schmidly, 1997; available at http://www.nsrl.ttu.edu/tmot1/), and the Wildlife Exposure Factors Handbook (USEPA, 1993), the body weight and food preference assigned to each hypothetical receptor are representative of specific species found in Texas. These species include the following:

- Small avian herbivore: field sparrow (*Spizella pusilla*), American goldfinch (*Carduelis tristis*), chipping sparrow (*Spizella passerine*), and black-throated sparrow (*Amphispiza bilineata*);
- Small avian insectivore: yellow-throated warbler (*Dendroica dominica*), yellow warbler (*Dendroica petechia*), Wilson's warbler (*Wilsonia pusilla*), red-faced warbler (*Cardellina rubrifrons*), red-eyed vireo (*Vireo olivaceus*), common yellow throat (*Geothlypis trichas*), and least flycatcher (*Geothlypis trichas*);
- Avian carnivore: broad-winged hawk (*Buteo platypterus*), Copper's hawk (*Accipiter cooperii*), northern harrier (*Circus cyaneus*), and red-shouldered hawk (*Buteo lineatus*);
- Avian piscivore: green heron (*Butorides virescens*), little blue heron (*Egretta caerulea*), and snowy egret (*Egretta thula);*
- Small mammalian herbivore: deer mouse (*Peromyscus maniculatus*), white-footed mouse (*Peromyscus leucopusfulvous*), eastern harvest mouse (*Reithrodontomys humulis*), western harvest mouse (*Reithrodontomys megalotis*), and white-ankled mouse (*Peromyscus pectoralis*);
- Small mammalian insectivore: southern short-tailed shrew (*Blarina carolinensis*) and desert shrew (*Notiosorex crawfordi*);
- Large mammalian herbivore: White-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*);
- Mammalian carnivore: red fox (*Vulpes vulpes*) and grey fox (*Urocyon cinereoargenteus*); and
- Mammalian piscivore*:* mink (*Mustela vison*).

In addition to birds and mammals, a short-term exposure scenario was established for terrestrial invertebrates (pollinators) to evaluate potential direct spray exposures. The

honeybee was selected as the receptor for this scenario since a standard contact toxicity test is required by the USEPA for pesticide registration.

A detailed description of the short-term (acute) and long-term (chronic) exposure scenarios evaluated by this ERA for birds, mammals, and terrestrial invertebrates are presented and discussed in the sections that follow. Factors that affect the dose of a given active ingredient (e.g., surface area, food ingestion rates, water ingestion rates, diets, and residual deposition rates) are also presented, discussed, and quantified where appropriate.

3.3.1.1 Short-Term (Acute) Exposure Scenarios

Three on-site scenarios were evaluated for avian and mammalian short-term exposures: 1) direct spray; 2) ingestion of contaminated food items (vegetation, insects, and small mammals); and 3) ingestion of surface water contaminated by an accidental spill. As discussed in Section 3.3.1, direct spray of a honeybee also was evaluated. The exposure assessments for terrestrial wildlife are summarized in ecological exposure assessment worksheets included in Volume II, Appendix D.

Direct Spray

In theory, wildlife species could be sprayed directly at the site of application during the broadcast application of any chemical. To address this potential exposure, three on-site, short-term (acute) exposure assessments were evaluated by a direct spray scenario: 1) direct spray of a bee (see Volume II, Appendix D); 2) direct spray of a small bird (ecological exposure assessment worksheets labeled F01b); and 3) direct spray of a small mammal. In each exposure assessment, it was assumed that the organism was sprayed over one-half of its surface area as the chemical is being applied at the site. Complete absorption was assumed within 24-hours of exposure. For a given chemical-receptor combination, the amount absorbed from direct spray was estimated by **Equation 3-1**:

$$AD_x = \frac{(Amnt_x)(P_x)}{BW}$$

where AD_x is the adsorbed dose of chemical x (mg/bee or, in the case of the small bird or small mammal, mg/kg-body weight or mg/kg-body weight/day), $Amnt_x$ is the amount of chemical x sprayed onto the surface of the organism (mg), P_x is the proportion of chemical x absorbed by the organism (unitless; assumed to be 1.0), and

BW is the body weight of the organism (kg). A body weight of 0.093 grams (0.000093 kg) was used for the bee (USDA, 2003a), while a body weight of 10 grams (0.01 kg) and 20 grams (0.02 kg) was selected for a small bird and small mammal, respectively (see Section 3.3.1).

The amount of a given chemical sprayed onto the surface of an organism (i.e., bee, small bird, or small mammal) was estimated by **Equation 3-2**:

$$Amnt_x = (AR_x)(SA_x)(0.5)$$

where AR_x is the application rate of chemical x (mg/cm^2), SA_x is the surface area of organism x (cm^2), and 0.5 is the assumed proportion of the organism's surface area that is sprayed (unitless). Application rates evaluated for each chemical (active ingredient expressed as lbs a.i./acre or lbs a.e./acre) were presented previously in Section 2.0. The surface area of a bee, small bird, and small mammal (2.64 cm^2, 46.5 cm^2, and 86.5 cm^2, respectively) was estimated using the methodology presented in the following paragraphs.

For the direct spray exposure assessments, general allometric relationships were used to model exposure. Allometry is defined as the study of the relationships of body size to various anatomical, physiological, or pharmacological parameters (Boxenbaum and D'Souza, 1990 and USEPA, 1993). Allometric relationships take the following general form (USEPA, 1993) (**Equation 3-3**):

$$Y = (a)(BW^b)$$

where *Y* is the biological characteristic to be predicted, *BW* is the animal's body weight (mass), and *a* and *b* are empirically derived constants. Once values are determined for *a* and *b*, the previous equation can be used to predict a value of *Y* from the body weight of the animal.

The surface area of a small bird and small mammal were estimated by allometric equations contained in the USEPA document entitled *Wildlife Exposure Factors Handbook* (USEPA, 1993). For the small bird, surface area was estimated using **Equation 3-4** (Walsberg and King, 1978):

$$SA_{skin} = (10)(BW^{0.667})$$

where SA_{skin} is the skin surface area beneath feathers (cm^2) and BW is small bird's body weight (g). Although the constant 10 in **Equation 3-4** was derived originally for domestic birds, Drent and Stonehouse (1971) verified the formula for birds in a variety of taxa and of weights spanning three orders of magnitude. Stahl (1967) developed a relationship between surface area and body weight from data for more than 100 mammals (**Equation 3-5**):

$$SA_{skin} = (0.11)(BW^{0.65})$$

where SA_{skin} is the skin surface area beneath hair (m^2), and BW is the body weight (kg). This equation was used to estimate the surface area of a small mammal. An allometric relationship relating surface area and body weight for insects (i.e., bees) was not identified from the literature. Therefore, the surface area of a bee was estimated using **Equation 3-5**.

Allometric relationships dictate that small birds and mammals will be exposed to much greater amounts of a chemical per unit body weight, compared with large birds and mammals. Therefore, direct spray exposure assessments are not given for a large bird or large mammal. Exposure assessments also are not given for indirect dermal contact with contaminated vegetation. For this exposure scenario, some estimates of dislodgeable residue and the rate of transfer from the contaminated vegetation to the surface of an animal must be available. No such data are available on wildlife dermal transfer rates for the compounds evaluated by this ERA. A study by Harris and Solomon (1992) estimated the dislodgeable residue of 2,4-D on humans as a proportion of the application rate shortly after application (0.1). If it were assumed that this value would also apply to wildlife and that the concentration of the chemical on the surface of the animal is equal to the dislodgeable residue on the vegetation, the absorbed dose resulting from the contact with contaminated vegetation would be one-tenth of that associated with a direct spray scenario.

Ingestion of Contaminated Food Items

Terrestrial animals could be exposed to any applied chemical from the ingestion of contaminated food items. Seven exposure assessments are presented for the acute (short-term), on-site consumption of contaminated food items at the point of application: 1) ingestion of contaminated vegetation by a small avian herbivore; 2) ingestion of contaminated vegetation by a small mammalian; 3) ingestion of contaminated vegetation by a large mammalian; 4) ingestion of contaminated insects

by a small avian insectivore; 5) ingestion of contaminated insects by a small mammalian insectivore; 6) ingestion of contaminated small mammals by an avian carnivore; and 7) ingestion of contaminated small mammals by a mammalian. Each exposure assessment assumes consumption of food items on-site for a period of one-day (24-hours), beginning shortly after application of the chemical. Chemical drift and degradation are not considered. It is also assumed that contaminated food items account for 100 percent of each receptor's diet. For a given chemical-receptor combination, the dietary intake (i.e., dose) is estimated by **Equation 3-6**:

$$DI_x = \frac{(C_{xi})(FIR)}{BW}$$

where DI_x is the dietary intake of chemical x (mg/kg-body weight/day), C_{xi} is the concentration of chemical x on food item i, FIR is the food ingestion rate (kg/day), and BW is the body weight (kg). The body weights selected for a hypothetical small avian herbivore, small avian insectivore, avian carnivore, small mammalian herbivore, small mammalian insectivore, large mammalian herbivore, and mammalian carnivore were presented previously and discussed in Section 3.3.1.

Food ingestion rates for each hypothetical receptor were estimated by allometric equations developed by Nagy (1987), which estimate food ingestion rates for birds and mammals from metabolizable energy (gross energy in unit of food consumed) and free-living metabolic rates (total daily energy requirements for an animal in the wild). This approach is consistent with USEPA (2005d) methodology. The specific allometric equations used are listed as follows:

- Small avian herbivore and small avian insectivore (allometric equation for passerine birds [i.e., perching birds or, less accurately, song birds]) (**Equation 3-7**):

$$FIR = (0.398)(BW^{0.850})$$

- Avian carnivore (allometric equation for non-passerine birds) (**Equation 3-8**):

$$FIR = (0.301)(BW^{0.751})$$

- Small mammalian herbivore and small mammal insectivore (allometric equation for rodents) (**Equation 3-9**):

$$FIR = (0.621)(BW^{0.564})$$

- Large mammalian herbivore (allometric equation for herbivores) (**Equation 3-10**):

$$FIR = (0.577)(BW^{0.727})$$

- Mammalian carnivore (allometric equation for all mammals) (**Equation 3-11**):

$$FIR = (0.235)(BW^{0.822})$$

where *FIR* is the food ingestion rate (g/day) and *BW* is the body weight (g). The allometric equations listed previously yield body weight-dependent estimates of food ingestion rates in terms of dry-weight for the food item (i.e., g/day-dry weight). An adjustment was made to account for the fresh-weight food items encountered by wildlife in the field. This adjustment was accomplished by **Equation 3-12**:

$$FIR_{wet} = \frac{FIR_{dry}}{1 - fraction\ water\ content\ of\ food\ item}$$

The fraction water content of food items assigned to each hypothetical receptor was as follows:

- Small avian herbivore and small mammalian herbivore (seeds): 10 percent;
- Small avian insectivore and herbivore (small insects): 65 percent;
- Large mammalian herbivore (short grass): 80 percent; and
- Avian and mammalian carnivore (small mammals): 70 percent.

These assumptions of water content are supported by data presented in the *Wildlife Exposure Factors Handbook* (USEPA, 1993), which reports a water content for seeds equal to 9.3 percent, a water content for insects ranging from 61 to 69 percent, a water content for young grasses ranging from 71 to 86 percent, and a water content for small mammals equal to 68 percent. For a given receptor, the concentration of chemical *x* on food item *i* (C_{xi}) was estimated by **Equation 3-13**:

$$C_{xi} = (AR_x)(RR_{xi})(Drift_{xd})$$

where AR_x is the application rate of chemical x (lbs/acre), RR_{xi} is the residue deposition rate of chemical x on food item i (mg/kg per lbs/acre), and $Drift_{xd}$ represents the proportion of the on-site application rate of chemical x that drifts off-site to a distance d due to physical processes (unitless; a value of 1.0 was used for this acute exposure scenario since it is assumed that all vegetation consumed is located at the site of application).

The concentration of each chemical on vegetation (mg/kg) was estimated using the empirical relationships of Hoerger and Kenaga (1972) between application rate and concentration on vegetation, as modified by Fletcher et al. (1994). Fletcher et al. (1994) reported estimated pesticide residuals (mg/kg; typical and upper limits) on four food classifications shortly after application of 1 lb/acre: 1) short grass; 2) tall grass; 3) broadleaf/forage plants and small insects; and 4) fruits, pods, seeds, and large insects (see **Table 3-4**). In order to select an appropriate residual rate for a given food item, assumptions regarding the diet of each receptor were made. The specific food items selected for each receptor, based on the available food classifications listed previously, and their corresponding residual deposition rates are summarized in **Table 3-5**.

TABLE 3-4
ESTIMATED PESTICIDE RESIDUALS ON VARIOUS TYPES OF VEGETATION FOOD ITEMS

Type of Vegetation/Food Item	Typical Value (1) (mg/kg per lb/acre)	Upper Limit (1) (mg/kg per lb/acre)
Short grass	85	240
Tall grass	36	110
Broadleaf/forage plants and small insects	45	135
Fruits, pods, seeds, and large insects	7	15

Notes:
mg/kg = milligram per kilogram
lb/acre = pound per acre
(1) Values are from Fletcher et al. (1994).

Source; Project Team

TABLE 3-5
FOOD CLASSIFICATIONS AND RESIDUAL DEPOSITION RATE

Receptor	Assumed Diet	Residual Deposition Rate (mg/kg per lb/acre)
Small avian herbivore	100 percent seeds	15
Small avian insectivore	100 percent small insects	135
Small mammalian herbivore	100 percent seeds	15
Small mammalian insectivore	100 percent small insects	135
Large mammalian herbivore	100 percent short grass	240

Source; Project Team

Conservative, upper limit values for residual deposition rates were selected for each receptor. Similarly, one realistic food type with the highest residual deposition rate was selected. For example, the diet of a small insectivorous bird or small insectivorous mammal may include both small insects (residual deposition rate of 135 mg/kg per lb/acre) and large insects (residual deposition rate of 15 mg/kg per lb/acre [see **Table 3-4**]). However, a diet of 100 percent small insects was assumed for the hypothetical avian and mammalian insectivore. Similarly, the diet of a large mammal herbivore could include short grass (240 mg/kg per lb/acre), tall grass (110 mg/kg per lb/acre), broadleaf/forage plants (135 mg/kg per lb/acre), and fruit (15 mg/kg per lb/acre). Again, for this hypothetical receptor, the most conservative diet was assumed (100 percent short grass).

Residual deposition rates on small mammals (food item for the avian and mammalian carnivore) were not available from the literature. For a given chemical, the amount (mg) sprayed onto the surface of a small mammal by direct spray (derived by **Equation 3-2** in Section 3.3.1.1.) and the small mammal body weight (0.02 kg) were used to estimate the residual deposition rate (mg/kg) for this food item (**Equation 3-14**):

$$RR_{sm} = \frac{(AR_x)(SA_x)(0.5)}{BW}$$

A spill to an on-site pond was evaluated in this ERA for acute (short-term) drinking water exposures. However, short-term exposure assessments involving the ingestion of fish by a piscivorous bird and piscivorous mammal were not evaluated because it is considered that, in general, residues in fish will not reach sufficient levels to cause

significant exposures over short time scales. Log K_{ow} values and/or BCFs listed in **Table 2-1** also indicate that significant accumulation in fish would not be expected over the short-term (i.e., 24-hours) for the majority of chemicals. For example, the BCF values for eight chemicals evaluated in this report are less than 1.0, indicating little potential for bioaccumulation.

Ingestion of Contaminated Water

Surface water can be contaminated from a direct spill. Two on-site exposure assessments are presented for the acute consumption of surface water: 1) ingestion of contaminated surface water by a small bird; and 2) ingestion of contaminated surface water by a small mammal. Both exposure assessments assume an accidental spill (25 gallons for low-boom ground and handgun applications and 3 gallons for backpack applications) into a small, on-site pond (0.25-acre pond 1 meter in depth [1,000,000 liters]) with complete mixing. Exposure also is assumed to occur over a 24-hour exposure period, with the contaminated pond serving as the only source of drinking water for each receptor. Because this scenario is based on the assumption that exposure occurs shortly after the spill, degradation is not considered. For a given chemical, exposure would depend in part on the volume of spill, the size of the water body into which it is spilled, the time at which water consumption occurs relative to the time of the spill, and the amount of contaminated water that is consumed.

The concentration of each chemical in surface water was estimated by **Equation 3-15**:

$$C_{xsw} = \frac{(VS_x)(C_{FLDx})}{V_p}$$

where C_{xsw} is the concentration of chemical x in surface water (mg/L), VS_x is the spill volume of the solution (liters; assumed to be 25 gallons [i.e., 94.6 liters] or 3 gallons [i.e., 11.4 liters], C_{FLDx} is the concentration of chemical x in the field solution (mg/L), and V_p is the volume of surface water in the pond (liters). For a given chemical, the actual concentration in water would depend on the actual amount of compound spilled and the size of the water body into which it is spilled.

The ingested dose of chemical x in surface water was estimated by **Equation 3-16**:

$$D_x = \frac{(C_{xsw})(WIR)}{BW}$$

where D_x is the dose of chemical x from surface water ingestion (mg/kg-body weight/day), *WIR* is the water ingestion rate (L/day), and *BW* is the body weight (kg). A body weight of 0.01 kilograms was selected for the small bird, while a body weight of 0.02 kilograms was selected for a small mammal (see Section 3.3.1).

Allometric relationships were used to estimate drinking water exposures. The small bird and small mammal water ingestion rates were estimated from allometric equations (**Equations 3-17** and **3-18**, respectively) listed in USEPA (1993) and developed by Calder and Braun (1983) using measured body weights and drinking water ingestion rates from Calder (1981) and Skadhauge (1975):

$$WIR_{bird} = (0.059)(BW^{0.67})$$

$$WIR_{mammal} = (0.099)(BW^{0.90})$$

where *WIR* is the water ingestion rate (L/day) and *BW* is the body weight (kg).

On an individual basis, the allometric relationships between body weight and water ingestion rate dictate that larger animals will consume more water than do small animals. However, because larger animals have lower metabolic rates than smaller ones, small animals have a higher water consumption rate per unit body weight. This means that smaller animals will experience greater oral exposure from the ingestion of drinking water per unit body weight than will larger animals. For this reason, an acute exposure assessment for a large mammal or a large bird was not performed.

3.3.1.2 Long-Term (Chronic) Exposure Scenarios

Three scenarios were evaluated for avian and mammalian long-term exposures: 1) on-site and off-site ingestion of contaminated vegetation; 2) off-site ingestion of contaminated surface water; and 3) off-site ingestion of contaminated fish. Results of the long-term exposure assessments for terrestrial wildlife are included in Volume II, Appendix D.

Ingestion of Contaminated Vegetation

Three long-term exposure assessments are presented for the on-site consumption of contaminated vegetation: 1) ingestion of contaminated vegetation by a small avian herbivore; 2) ingestion of contaminated vegetation by a small mammalian herbivore; and 3) ingestion of contaminated vegetation by a large mammalian herbivore. Each

exposure assessment assumes consumption of food items at the point of application for a period of 90 days following application of the chemical. It was further assumed that contaminated vegetation accounts for 100 percent of the dietary intake for each receptor. Although drift was not considered for these chronic exposure assessments, chemical degradation on vegetation over the 90-day exposure period was addressed by deriving time-weighted average concentrations. For a given chemical-receptor combination, the ingested dose is estimated by **Equation 3-19**:

$$DI_x = \frac{(TWAC_{xi})(FIR)}{BW}$$

where DI_x is the dietary intake of chemical x (mg/kg-body weight/day), $TWAC_{xi}$ is the time-weighted average concentration of chemical x on food item i for the 90-day exposure period, FIR is the food ingestion rate of the receptor (kg/day), and BW is the body weight (kg). Food ingestion rates and body weights for the small avian herbivore, small mammalian herbivore, and large mammalian herbivore were presented previously and discussed in Section 3.3.1. The time-weighted average concentration of chemical x on food item i was estimated by **Equation 3-20**:

$$TWAC_{xi} = \frac{(C_{xi0})(1-\exp(-k_x T))}{k_x T}$$

where C_{xi0} is the initial concentration of chemical x on food item i on Day 0 of the exposure period (mg/kg; derived using **Equation 3-13**), k_x is the decay coefficient for chemical x on food item i, and T is the duration of exposure (days; assumed to be 90). The decay coefficient of chemical x on food item i was estimated by **Equation 3-21**:

$$k_{xi} = \frac{\ln(2)}{t_{50}}$$

where t_{50} is the half-life of chemical x on vegetation (see Section 2.0).

Three exposure assessments were considered for the chronic, off-site consumption of contaminated vegetation: 1) ingestion of contaminated vegetation by a small avian herbivore; 2) ingestion of contaminated vegetation by a small mammalian herbivore; and 3) ingestion of contaminated vegetation by a large mammalian herbivore. Off-site, chronic exposure assessments for these receptors used the methodology presented

previously for chronic, on-site exposures. However, the initial concentration of a chemical on a vegetative food item on day 0 (described by **Equation 3-13**) was based on the application rate and that proportion of the application rate that drifts to the exposure point (25 feet) and deposits on vegetation.

Drift is more or less a physical process that depends on droplet size and meteorological conditions rather than the specific properties of the chemical. Estimates of off-site drift can be modeled using AgDRIFT (Version 2.0.05), a model developed as a joint effort by the USEPA Office of Research and Development and the Spray Drift Task Force (a coalition of pesticide registrants). AgDRIFT provides estimates of drift based on the types of applications (aerial applications and ground applications [low boom spray, high boom spray, and orchard blast]). Low-boom, ground-spray applications were assumed for each chemical and application rate evaluated by this exposure scenario. Additional assumptions included droplet sizes based on very fine-to-fine spray and a wind speed of five miles per hour (mph) at the point of application. **Table 3-6** provides a summary of drift estimates (fraction of application rate) for seven distances from the point of application. Further details of AgDRIFT are available at http://www.agdrift.com/index.htm.

TABLE 3-6
CENTRAL ESTIMATES OF OFF-SITE DRIFT

Distance Down Wind (feet)	Proportion that Drifts (1)(2)
25	0.0158
50	0.0081
100	0.0044
300	0.0017
500	0.001
900	0.0006
990	0.0005

Notes:
(1) Expressed as a fraction of application rate (Derived by AgDRIFT Version 2.0.05).
(2) Estimates based on very fine to fine spray for low boom ground spray applications.
This will over-estimate drift for applications involving larger droplets.

Source: Project Team

Off-Site Ingestion of Contaminated Surface Water

Two exposure assessments were conducted for the off-site ingestion of contaminated surface water: 1) ingestion of contaminated surface water by a small bird; and 2) ingestion of contaminated surface water by a small mammal. Both exposure assessments are based on the migration of applied chemicals with surface runoff and groundwater to an off-site pond (1-hectare pond 2 meters in depth [20,000,000 liters]) adjacent to a one-hectare treated plot. Exposure is assumed to occur for a period of ninety days, with the off-site pond serving as the only drinking water source.

The migration of applied herbicides/insecticides was quantified using a web-based application (NAPRA WWW) of the GLEAMS Model Version 3.0 (Groundwater Loading Effects of Agricultural Management Systems). The web-based application of GLEAMS (NAPRA GLEAMS) examined the fate of chemicals in various soils under different meteorological and hydrogeological conditions. Outputs of NAPRA GLEAMS, expressed as yearly estimates of runoff volume per unit area (inches/hectare), groundwater volume per unit area (inches/hectare), mass of a chemical in surface runoff per unit area (mg/hectare), and mass of a chemical in groundwater per unit area (mg/hectare), were used to estimate the concentration of active ingredient in the off-site pond. A detailed description of the NAPRA GLEAMS model, input parameters and assumptions, as well as model outputs is presented in Baker (2006). A summary of model outputs used to estimate surface water concentrations are presented in the paragraphs that follow.

The specific data used to estimate the concentration of a given chemical in pond surface water were dictated by the specific outputs generated by the NAPRA GLEAMS model. As detailed in Baker (2006), hundreds of soil types were identified in Texas based on a number of characteristics, including saturated conductivity, rooting depth, soil water content, number of soil horizons, depth to each soil horizon, porosity, field capacity, organic matter content, water content at wilting point, clay content, silt content, and pH. Given the number of soil types found in Texas and the number of weather regions assigned to the state based on factors that included precipitation (see Baker, 2006), over 4,600 unique combinations of soil type and weather conditions were identified and modeled by NAPRA GLEAMS (Baker, 2006). Each unique combination was modeled on a daily basis for a period of 60 years. Therefore, 60 yearly estimates of total inches of surface runoff per unit area and 60 yearly estimates of total inches of groundwater per unit area were generated for each unique combination of soil type and weather

condition. In addition, for a given herbicide/insecticide and application rate, 60 yearly estimates of total mass in surface runoff per unit area and 60 yearly estimates of total mass in groundwater per unit area were generated for each unique soil type and weather condition (see **Table 3-7**).

For each unique soil type and weather condition, 50 percent upper confidence limit (UCL) values were derived for surface runoff and groundwater volume. Similarly, for a given herbicide/insecticide and application rate, 50 percent UCL values were derived for the mass in surface runoff and the mass in groundwater. Maximum 50 percent UCL values for surface runoff volume, groundwater volume, mass in surface runoff, and mass in groundwater served as the basis for deriving estimated concentrations in pond surface water (see **Table 3-7** for estimated surface water concentrations for each active ingredient and application rate). The specific computational methods used to estimate the concentration of each chemical in a hypothetical pond are presented and discussed in the following paragraphs.

TABLE 3-7
ESTIMATED CONCENTRATIONS IN OFF-SITE POND SURFACE WATER

Active Ingredient	Product	Application Rate (1) (lb/acre)	Concentration in Surface Water (1)(2) (mg/L)
Glyphostae - isopropylamine salt	Roundup Pro	0.1875 lb/acre	1.26E-08
	Roundup Pro	0.3735 lb/acre	9.16E-09
	Roundup Pro	3 lb/acre	3.51E-07
	Aquamaster	8 lb/acre	4.48E-01
Glyphostae - potassium salt (3)	Roundup Original Max	0.1875 lb/acre	1.26E-08
	Roundup Original Max	0.3735 lb/acre	9.16E-09
	Roundup Original Max	3 lb/acre	3.51E-07
Sulfometuron methyl	Oust	0.09375 lb/acre	1.79E-09
	Landmark MP	0.0703 lb/acre	1.31E-09
	Landmark MP	0.0352 lb/acre	6.53E-10
Sulfosulfuron	Outrider	0.0623 lb/acre	1.38E-08
Metsulfuron methyl	Escort XP	0.0375 lb/acre	1.87E-08
	Escort XP	0.1125 lb/acre	5.68E-08
Fluroxypyr	Vista	0.1174 lb/acre	7.19E-09
Triclopyr - butoxyethyl ester (BEE)	Pathfinder II (4)	1.882 lb/acre	NA
	Pathfinder II (4)	3.764 lb/acre	NA
Triclopyr - triethylamine salt (TEA)	Garlon 3a	0.75 lb/acre	6.81E-07

TABLE 3-7
ESTIMATED CONCENTRATIONS IN OFF-SITE POND SURFACE WATER

Active Ingredient	Product	Application Rate (1) (lb/acre)	Concentration in Surface Water (1)(2) (mg/L)
Clopyralid	Transline	0.2345 lb/acre	1.98E-09
	Transline	0.4925 lb/acre	4.11E-08
Chlorsulfuron	Landmark MP	0.0234 lb/acre	1.44E-08
	Landmark MP	0.0117 lb/acre	7.18E-09
Methoprene	Altosid XR	0.00025 lb/ft^3	2.02E-02
Amino Pyralid	Milestone VM	0.1097 lb/acre	5.15E-09
Imazapyr	Habitat	0.99 lb/acre	2.91E-07
Fenoxycarb	Award	0.01 lb/acre	2.16E-14

Notes:
NA = Not applicable
(1) Values express as acid extractable (clopyralid, fluroxypyr, glyphosate - isopropylamine salt, glyphosate - potassium salt, imazapyr, and triclopyr - butoxyethyl ester, and triclopyr - triethylamine salt) or active ingredient (sulfometuron methyl, sulfosulfuron, metsulfuron methyl, chlorsulfuron, amino pyralid, and fenoxycarb).
(2) With the exception of Aquamaster (glyphosate - isopropylamine salt) and Altosid XR (methoprene), surface water concentrations based on yearly maximum 50 percent UCL for surface run-off flow, groundwater flow, mass in surface run-off, and mass in groundwater (see Baker, 2006) and a pond volume of 20,000,000 liters. The concentration of methoprene and glyphosate-isopropylamine salt in surface water was estimated using application rates.
(3) Application rates for Roundup Original Max assumed to be identical to current application rates for Roundup Pro. Roundup Original Max is not currently being used by TxDOT in its Roadside Pest Management Program.
(4) Pathfinder II used in basal bark applications only (no broadcast applications). As such, migration with surface run-off and groundwater to an off-site pond is not considered a potentially complete transport pathway.

Source: Project Team

The total mass of a given chemical entering the hypothetical pond on a yearly basis ($Mass_{xp}$) was derived by **Equation 3-22**:

$$Mass_{xp} = (Mass_{xsr}) + (Mass_{xgw})$$

where $Mass_{xsr}$ is the maximum 50 percent UCL value for the mass of chemical x in surface runoff (mg) and $Mass_{xgw}$ is the maximum 50 percent UCL value for the mass of chemical x in groundwater (mg). The concentration of a given chemical in pond surface water (C_{xsw}) was estimated by **Equation 3-23**:

$$C_{xsw} = \frac{Mass_x}{(V_p)}$$

where $Mass_x$ is the mass of chemical x entering the hypothetical pond on a yearly basis (mg) and V_p is the volume of the hypothetical pond (assumed to be 20,000,000 liters).

The ingested dose of a given chemical in surface water was derived using **Equation 3-16.**

Altosid XR (methoprene) and Aquamaster (glyphosate-isopropylamine salt) are applied directly to surface water (Altosid XR) or to aquatic (emergent) vegetation (Aquamaster). Therefore, the methodology presented previously for estimating surface water concentrations does not apply to these two pesticides/insecticides. Concentrations were estimated from their respective application rates. For example, the application of glyphosate-isopropylamine salt is 8.0 lbs a.e./acre (or 19.75 lb a.e./hectare. Based on a volume of 20,000,000 liters, this application rate would result in a surface water concentration of 0.448 mg a.e./L (assumes complete mixing within the pond).

Off-Site Ingestion of Contaminated Fish

Three long-term exposure assessments are presented for the off-site consumption of contaminated fish: 1) ingestion of contaminated fish by an avian piscivore; and 2) ingestion of contaminated fish by a mammalian piscivore. Exposure is assumed to occur for a period of ninety days, with the off-site pond serving as the only source of fish consumed by each receptor. For a given chemical-receptor combination, the dietary intake (i.e., dose) from fish ingestion was estimated by **Equation 3-24**:

$$DI_{xf} = \frac{(C_{xf})(FIR)}{BW}$$

where DI_{xf} is the dietary intake of chemical x from fish consumption (mg/kg-body weight/day), C_{xf} is the concentration of chemical x in fish, FIR is the food ingestion rate (kg/day), and BW is the body weight (kg). The body weights selected for a hypothetical avian piscivore and mammalian piscivore were presented previously and discussed in Section 3.3.1. The food ingestion rate of the hypothetical avian piscivore was estimated using a regression equation developed by Kushlan (1978), which relates the amount of food ingested per day to body weight for wading birds (**Equation 3-25**):

$$\log(FIR) = (0.966)(BW) - 0.640$$

where FIR is the food ingestion rate for the avian piscivore (g/day-dry weight) and BW is the body weight of the avian piscivore (g). The food ingestion rate for the mammalian piscivore was estimated using the allometric relationship for all mammals (see **Equation 3-11**). Because the regression equation developed by Kushlan (1978) for

wading birds and the allometric relationship developed by Nagy (1987) for all mammals yield body weight-dependent estimates of food ingestion rates in terms of dry-weight for the food item (i.e., g/day-dry weight), an adjustment was made using **Equation 3-12** to account for the fresh-weight of fish encountered by piscivores in the field. The fraction water content of fish was assumed to be 0.75. This is a reasonable assumption based a value of 75 percent for boney fish reported in the *Wildlife Exposure Factors Handbook* (USEPA, 1993). The concentration of a given chemical in fish was estimated by **Equation 3-26**:

$$C_{xf} = (C_{xsw})(BCF_x)$$

where C_{xsw} is the concentration of chemical x in pond surface water (mg/L; estimated by **Equation 3-21**) and BCF_x is the bioconcentration factor for chemical x in fish (L/kg). BCFs for each chemical were estimated using the following regression equation (**Equation 3-27**) from Lyman et al. (1990):

$$\log BCF = (0.76)(\log K_{ow}) - 0.23$$

where K_{ow} is the octanol-water partition coefficient for chemical x (unitless; see Section 2.0 for chemical-specific K_{ow} values). It is note that **Equation 3-27** does not take into account metabolism; therefore, this method of estimation will overstate bioconcentration for those active ingredients readily metabolized by fish.

3.3.2 Aquatic Species

Potential acute effects on aquatic species (i.e., fish, amphibians, aquatic invertebrates, phytoplankton. and macrophytes) are based on estimated concentrations in an on-site pond contaminated by an accidental spill (see on-site ingestion of contaminated water under Section 3.3.1.1), while chronic effects on aquatic species are based on estimated concentrations in an off-site pond contaminated by chemicals migrating with surface runoff and groundwater (based on NAPRA GLEAMS modeling; see off-site ingestion for contaminated water in Section 3.3.1.2 and Baker, 2006). All chemicals were evaluated under the acute exposure scenario; however, Pathfinder II was excluded from evaluation under the chronic scenario based on an incomplete exposure pathway (see Section 3.1.1).

3.4 RISK CHARACTERIZATION

The risk characterization is the final phase of the ERA, where exposure and ecological effects are integrated into an overall conclusion (risk estimation). In this phase, levels of exposure (e.g., estimated environmental concentration [EEC] or dose) were compared to the TRVs summarized in **Table 3-2**. As shown by **Equation 3-28**, acute and/or chronic risk estimates for a given chemical-receptor combination were derived by dividing levels of exposure (i.e., EECs or doses) by the acute and/or chronic TRVs:

$$HQ = \frac{EEC}{TRV} \qquad or \qquad HQ = \frac{Dose}{TRV}$$

where HQs greater than a value of 1.0 indicates the potential for risk since the EEC or dose exceeds the TRV.

3.4.1 Terrestrial Wildlife

The risk characterization for birds, mammals, and terrestrial invertebrates (honeybees) is summarized in the chemical-specific ecological worksheets (see Volume II, Appendix D). Risk estimates are based on chemical-specific application rates (expressed as lbs a.i./acre or lbs a.e./acre) used by TxDOT for each product. When a given active ingredient is present in the same product applied at different application rates or in multiple products applied at different application rates, risk estimates are provided for each application rate and product used.

3.4.1.1 Direct Spray

Risk estimates for acute exposures involving the direct spray of a honeybee, small bird, and small mammal are less than 1.0 for each herbicide/insecticide. Therefore, adverse impacts to species represented by generic receptor categories resulting from the chemicals used or planned for use by TxDOT are unlikely.

3.4.1.2 Ingestion of Contaminated Food Items

On-site and off-site risk estimates involving the acute and/or chronic consumption of contaminated food items (vegetation, insects, small mammals, and fish) were less than 1.0 for amino pyralid (Milestone VM), chlorsulfuron (Landmark MP), clopyralid (Transline), fenoxycarb (Award), fluroxypyr (Vista), imazapyr (Habitat), metsulfuron methyl (Escort XP), sulfometuron methyl (Landmark MP and Oust XP), and

sulfosulfuron (Outrider). Therefore, adverse effects to birds or mammals resulting from the use of these chemicals at the application rates used by TxDOT are unlikely.

Risk estimates for glyphosate-isopropylamine salt (Roundup Pro), glyphosate-potassium salt (Roundup Original Max), and triclopyr-TEA (Garlon 3a) exceeded 1.0 for the on-site ingestion of insects by small mammal insectivores. HQ values ranged from 1.12 for glyphosate-isopropylamine salt and glyphosate-potassium salt (application rate of 3.0 lbs a.e./acre) to 1.63 for triclopyr-TEA (application rate of 0.75 lb a.e./acre).

Based on the conservative exposure assessment and risk characterization the potential for adverse impacts to small mammal insectivores exists because of the use of these chemicals within the ROW.

In addition to the acute (on-site) scenario described previously, risk estimates for triclopyr-TEA (Garlon 3a) also exceeded 1.0 for one chronic, on-site exposure scenario (ingestion of contaminated vegetation by a large mammal herbivore; HQ = 1.17 at an application rate of 0.75 lb a.e./acre).

Large mammalian herbivores (e.g., white-tailed deer) consume a variety of food items in the wild (Davis and Schmidly, 1997), including tall grass, broadleaf plants, and fruit. Upper residual deposition rates for these food items (110 mg/kg per lb/acre for tall grass, 135 mg/kg per lb/acre for broadleaf/forage plants and 15 mg/kg per lb/acre for fruit) are lower than the upper residual deposition rate for short grass (240 mg/kg per lb/acre). The use of the maximum residual deposition rate in the exposure assessment represents a conservative exposure assumption since the typical residual deposition rate for short grass is lower than the maximum residual deposition rate (see **Table 3-4**).

The conservative assumption was made that 100 percent of the food consumed during the exposure period comes from the point of application for chronic, on-site exposures. This is a reasonable assumption for small mammals (Davis and Schmidly [1997] report a maximum home range of 0.2 hectares for the white-footed mouse). However, it is not applicable to large mammalian herbivores (Davis and Schmidly [1997] report a home range up to 289 hectares for white-tailed deer).

To evaluate the impact that the conservative exposure assumptions have on risk estimates, HQ values were recalculated using: 1) the typical residual deposition rate on short grass (i.e., 85 mg/kg per lb/acre); 2) the average of the short grass, tall grass, and

broadleaf forage plant upper residual deposition rate (162 mg/kg per lb/acre); and 3) an Area Use Factor (AUF) of 0.5 (i.e., the large mammal herbivore obtains 50 percent of its food at the point of application during the exposure period). The HQ value based on the typical residual rate on short grass (85 mg/kg per lb/acre) is 0.41, the HQ value based on the average of the short grass, tall grass, and broadleaf forage plant upper residual deposition rate (162 mg/kg per lb/acre) is 0.79, and the HQ based on an AUF of 0.5 is 0.59.

In summary, the conservative exposure assessment and risk characterization indicates potential for adverse impacts to large mammal herbivores feeding on-site for a period of 90 days following application of triclopyr-TEA (Garlon 3a).

Risk estimates for methoprene exceeded 1.0 for the chronic, off-site consumption of contaminated fish by an avian piscivore (HQ = 27.2). Altosid XR is applied directly to surface water at a rate of one briquette/200 cubic feet of water. Assuming that the entire briquette instantaneously dissolved in 200 cubic feet of water, the concentration in surface water would be 0.0202 mg a.i/L. Methoprene briquets have been reported as having a relatively long half-life in water, where mean degradation of the briquettes was 19 percent by weight after 150 days of submergence (Boxmeyer et al., 1997). Because Altosid XR briquets release methoprene slowly into water, a concentration of 0.0202 mg/L represents a theoretical "maximum" concentration.

Environmental fate data also indicate that when released to surface water methoprene dissipates quickly (90 percent degradation within three days) through microbial metabolism and photolysis (degradation through reaction with sunlight) (USEPA, 1991a). Half-life values for water reported by Schooley et al. (1975) (approximately 30 hours at 0.001 mg/L and 40 hours at 0.01 mg/L) and Wright (1976; cited in Glare and O'Callaghan, 1999) (less than 2 days) also indicate rapid dissipation. Finally, the method used to estimate the BCF value for methoprene likely overstates the potential for this chemical to bioconcentrate in fish tissue since metabolism by fish is not accounted for in the risk calculation. Because fish can rapidly metabolize methoprene (Glare and O'Callaghan, 1999), significant bioaccumulation would not be expected in fish tissue.

3.4.1.3 Ingestion of Contaminated Surface Water

With the exception of triclopyr-BEE (Pathfinder II) risk estimates for the acute ingestion of surface water from an on-site pond immediately following an accidental spill are less

than 1.0. The triclopyr-BEE HQ value for acute ingestion by a small bird and small mammal was 3.75 and 4.98, respectively. The exposure assessment is based on a spill volume of 25 gallons entering a 0.25-acre pond 1 meter in depth (volume of 1,000,000 liters). As stated in Section 3.3.1.1, the spill scenario is dominated by the specific assumptions used to estimate exposure. For a given chemical, the actual concentration in water would depend on a number of factors, including the volume of the spill and the volume of the water body into which it spilled. Regardless, an accidental release of triclopyr-BEE to a surface water body has the potential to adversely affect small birds and mammals using that surface water body as a drinking water source.

3.4.2 Aquatic Species

An acute and chronic exposure assessment was performed for aquatic life (fish, amphibians, aquatic invertebrates, phytoplankton, and macrophytes). The acute exposure assessment involved the accidental spill of each chemical (excluding Altosid XR) to an on-site pond. With the exception of Pathfinder II (active ingredient is triclopyr-BEE), a spill volume of 25 gallons was assumed for all formulations. A spill volume of 3 gallons was assumed for Pathfinder II since this chemical is applied only by backpack (backpack units used by TxDOT have a volume of three gallons).

The chronic exposure assessment involves the migration of active ingredients with surface runoff and groundwater to an off-site pond. As discussed in Section 3.3.1.2, NAPRA GLEAMS was used to estimate the yearly mass of each active ingredient migrating with surface runoff and groundwater to the off-site pond. The sections that follow present the risk characterization for each scenario.

3.4.2.1 Accidental Spill to an On-Site Pond

Risk estimates for acute exposures to chemicals in an on-site pond following an accidental spill are presented in chemical-specific ecological worksheets included in Volume II, Appendix D. Surface water concentrations were derived using **Equation 3-15**. With the exception of amino pyralid (Milestone VM), clopyralid (Transline), and glyphosate-isopropylamine salt (Aquamaster), an accidental spill (25 gallons) of each formulation would result in HQ values greater than 1.0 to one or more of the aquatic species evaluated.

Algae and macrophyte TRVs were not identified from the literature for methoprene (Altosid XR) and fenoxycarb (Award). Eight chemicals (i.e., sulfosulfuron [Outrider],

metsulfuron methyl [Escort XP], fluroxypyr [Vista], triclopyr-BEE [Pathfinder II], triclopyr-TEA [Garlon 3a], chlorsulfuron [landmark MP], imazapyr [Habitat], and fenoxycarb [Award[) also lack toxicity data for amphibians. Based on the lack of TRVs, risk estimates for these chemical-receptor combinations could not be derived.

The U.S. Fish and Wildlife Service (USFWS, 2004) classifies active ingredient of pesticides according to a system of seven pesticide ecotoxicity classes (four ecotoxicity classes for animal species and three ecotoxicity classes for plants) and eighteen groupings of species, including amphibians. The four ecotoxicity classes covering the range of pesticide toxicity to animal species are as follows:

- Class 0: This class includes pesticides that are practically non-toxic to a specific group of animal species;
- Class 1: This class includes pesticides that are slightly to moderately toxic to a specific group of animal species;
- Class 2: This class includes pesticides that are highly toxic to a specific group of animal species; and
- Class 3: This class includes pesticides that are very highly toxic to a specific group of animal species.

An ecotoxicity rating of zero was assigned to chlorsulfuron, imazapyr, and triclopyr-TEA, indicating that these three pesticides are practically non-toxic to amphibians. Fenoxycarb, fluroxypyr, and metsulfuron methyl were assigned an ecotoxicity rating of one, indicating that these three pesticides are slightly to moderately toxic to amphibians (USFWS, 2004). Finally, an ecotoxicity rating of two was assigned to triclopyr-BEE, indicating that this compound is highly toxic to amphibians. While these ecotoxicity ratings cannot be used to quantitatively evaluate potential risks, they do indicate that an accidental spill of fenoxycarb, fluroxypyr, metsulfuron methyl, or triclopyr-BEE have the potential to adversely impact amphibians.

Based on risk calculations completed for this report and USFWS data, aquatic organisms could be adversely affected by accidental spills of chemical formulations in surface water bodies. Such effects would depend on the size of the spill, the size of the surface water body into which it is spilled, and the specific species present within the water body and the life stage of those species.

3.4.2.2 Migration with Surface Runoff and Groundwater to an Off-Site Pond

Risk estimates for chronic exposures to chemicals migrating with surface-runoff and groundwater to an off-site pond are presented in chemical-specific ecological worksheets in Volume II, Appendix D. Surface water concentrations were modeled using NAPRA GLEAMS or, in the case of glyphosate-isopropylamine salt (Aquamaster) and methoprene (Altosid XR), estimated using application rates and field solution concentrations. With the exception of glyphosate-isopropylamine salt (Aquamaster), estimated surface water concentrations are less than surface water screening values for each chemical-receptor combination. Chronic risk estimates for glyphosate-isopropylamine salt (Aquamaster) exceeded 1.0 for fish (HQ = 1.24). The surface water concentration used in the risk characterization assumes 100 percent application directly to surface water without consideration for foliar interception. Degradation within the pond or partitioning to sediment was not considered. Based on a chronic TRV of 0.36 mg/L and an estimated surface water concentration of 0.45 mg/L, potential exists for adverse impacts to fish populations under this scenario.

Several chemicals lacked chronic TRVs for amphibians and/or aquatic plants (see Section 3.4.2.1). Based on modeled surface water concentrations and risk estimates for other aquatic organisms (i.e., fish and aquatic invertebrates), it is unlikely that migration from the point of application to an off-site pond would impact these receptors. Identical to the acute scenario involving an accidental spill, risk estimates are dependent on the size of the surface water body. The hypothetical pond used in this scenario is consistent with USEPA methodology (USEPA, 2004d); however, runoff from application sites can also enter roadside ditches.

These ditches serve as habitat for amphibians, including several species listed as threatened by the Texas Parks and Wildlife Department (TPWD) such as the black spotted newt (*Notophthalmus meridionalis*) and white-lipped frog (*Leptodacylus labialis*). Although risk estimates were not derived for a roadside ditch scenario, direct spray/direct application, spray drift, or migration with surface soil via surface runoff would have the potential to adversely affect amphibians using roadside ditches as feeding and breeding habitat.

3.4.3 Summary of Risk Characterization

Risk estimates for some of the exposure scenarios evaluated by this ERA indicate that some active ingredients found in chemical formulations used or planned for use by TxDOT in its Roadside Pest Management Program could result in adverse effects to ecological receptors. Specifically, risk estimates for seven chemical-receptor-exposure pathway combinations exceeded 1.0:

- Acute, on-site ingestion of contaminated insects by a small mammalian insectivore: Roundup Pro (glyphosate-isopropylamine salt);
- Acute, on-site ingestion of contaminated insects by a small mammalian insectivore: Roundup Original Max (glyphosate-potassium salt);
- Acute, on-site ingestion of contaminated insects by a small mammalian insectivore: Garlon 3a (triclopyr-TEA);
- Chronic, on-site ingestion of contaminated vegetation by a large mammalian herbivore: Garlon 3a (triclopyr-TEA);
- Chronic, off-site ingestion of contaminated fish by an avian piscivore: Altosid XR (methoprene);
- Acute, on-site ingestion of surface water by a small bird following an accidental spill: Pathfinder II (triclopyr-BEE); and
- Acute, on-site ingestion of surface water by a small mammal following an accidental spill: Pathfinder II (triclopyr-BEE).

An accidental release of triclopyr-BEE to a surface water body has the potential to adversely affect small birds and mammals using that surface water body as a drinking water source. An accidental spill of any formulation to an on-site pond also has the potential to adversely impact fish, amphibians, aquatic invertebrates, and aquatic plants.

For a given chemical, the actual concentration in water would depend on a number of factors, including the volume of the spill and the volume of the water body into which it spilled. For the off-site pond exposure scenario, glyphosate-isopropylamine salt (Aquamaster) has the potential to impact fish populations (HQ = 1.24). Identical to the acute (on-site) pond scenario, risk estimates are dependent on a number of factors, including the volume of the surface water body.

3.5 UNCERTAINTIES

The procedures used in this evaluation to assess risk to ecological receptors are subject to uncertainties due to lacking data in the literature and the need to make certain assumptions and extrapolations. The major uncertainties associated with the ERA and their effect on risk conclusions are presented and discussed in the following:

Toxicity Reference Values

- Acute and/or chronic toxicity data for several chemical-receptor combinations were not available from the literature. In general, receptors lacking chemical-specific toxicity data were amphibians and aquatic plants. Without a TRV, risk estimates for affected chemical-receptor combinations could not be derived for certain exposure scenarios;
- A second source of uncertainty related to TRVs concerns the lack of literature-based acute NOEL/NOEC values for several chemical-receptor combinations. In these cases, NOEL/NOEC values were estimated using conservative safety factors (LOCs) established by the USEPA (2004d). A safety factor of 10 was used for birds and mammals, while a safety factor of 20 was used for fish, aquatic invertebrates, and amphibians. The use of safety factors to estimate acute NOEL/NOEC values may overstate or understate potential for risk;
- A third source of uncertainty associated with the TRVs applies to chronic TRVs for several chemical-receptor combinations. When chronic toxicity test data were not identified from the literature, chronic TRVs were estimated by applying a safety factor of 100 to the minimum acute NOEL/NOEC identified from the literature. In the absence of an experimental acute NOEL/NOEC, the chronic TRV was estimated by applying a safety factor of 100 to the minimum EC_{50}, LC_{50}, or LD_{50} identified from the literature (USEPA, 1997a). Chronic TRVs estimated from minimum acute NOEL/NOEC values likely resulted in an over-statement of potential risk; and
- A fourth source of uncertainty related to TRVs applies to the low number of species that have been tested for toxicity. For many chemical-receptor combinations, only a limited number of species have been tested for toxicity. Therefore, the TRVs used in this ERA may not be protective of all possible ecological receptors. This uncertainty was reduced by selecting minimum toxicity values for each chemical-receptor combination with more than one toxicity value.

Exposure Assessment

- As discussed in Section 3.1.1, certain potential exposure pathways and/or routes were not evaluated by this ERA, including inhalation of spray particles, dermal contact with contaminated abiotic media (e.g., surface soil and sediment), or vegetation, and incidental ingestion of contaminated abiotic media. Although complete, these pathways were considered insignificant relative to other exposure pathways and/or routes that were evaluated. For this generic (i.e., non site- or species-specific) Risk Assessment, an attempt was made to limit the number of exposure scenarios;
- A second source of uncertainty associated with the exposure assessment was the exclusion of an exposure scenario for terrestrial plants. Many of the chemicals used by TxDOT in its Roadside Pest Management Program are designed to produce adverse effects on terrestrial plants. In turn these same chemicals may affect non-target plant species due to direct spray and/or spray drift under certain application conditions and circumstances; and
- A third source of uncertainty related to the exposure assessment is the use of extremely conservative exposure parameters. For this evaluation, upper limit estimates of residual deposition rates were assumed for each receptor food item. Furthermore, it was assumed that each receptor obtains 100 percent of its diet at the exposure point (point of application or location of off-site migration).

Risk Characterization

- Risk estimates were derived on a compound-by-compound basis. That is, the Risk Assessment considered independent effects of chemicals, which could result in an under-estimation of risk for exposures to multiple chemicals if there are additive or synergistic effects. Furthermore, the ERA did not consider multiple application scenarios. Based on information contained in the *Herbicide Operations Manual* (TxDOT, 2004) and Baker (2006), multiple applications of glyphosate-isopropylamine salt (Roundup Pro) and glyphosate-potassium salt (Roundup Original Max) can occur during the exposure periods evaluated by this ERA; and
- A second source of uncertainty associated with the risk characterization applies to the derivation of risk estimates on an exposure-by exposure basis. As discussed in Section 3.2, in determining the level of exposure for birds and mammals, two time scales were considered: 1) short-term (acute) exposures

representing relatively high levels of exposure over a short period of time (i.e., 24-hour exposure period beginning shortly after application); and 2) long-term (chronic) exposures representing low levels of exposure over an extended period of time (i.e., 90-day exposure period beginning shortly after application). Both time scales included exposure scenarios for the ingestion of surface water and ingestion of contaminated food items by a small bird and a small mammal. However, an overall ingestion dose was not obtained and used in the derivation of risk estimates. This resulted in an under-statement of potential risks for each chemical-receptor combination with multiple ingestion pathways for a given time scale. Risk estimates for surface water ingestion were generally orders of magnitude less than risk estimates for ingestion of contaminated food for those chemicals with complete exposure pathways. Therefore, combining risk estimates from both exposure pathways would have minimal influence on risk estimates.

4.0 HUMAN HEALTH RISK ASSESSMENT

This section presents the HHRA for active ingredients in the various chemicals used or planned for use by TxDOT in its Roadside Pest Management Program. This HHRA was conducted as a part of TxDOT's effort to supplement its FEIS for its Roadside Pest Management Program. TxDOT completed the FEIS in 1996 and since that time, new techniques, chemicals, and procedures have become available. A supplement is necessary in order to fully disclose and inform the public on the environmental impacts of the Pest Management Program and to adhere to state rules. The HHRA was conducted in four phases: 1) hazard identification; 2) exposure assessment; 3) dose-response assessment; and 4) risk characterization. Each phase is presented and discussed within the subsections that follow.

4.1 HAZARD IDENTIFICATION

The hazard identification describes the types of effects the pesticides used by TxDOT in its Roadside Pest Management Program may produce in human receptors. It is based on a review of the available toxicological data and involves making judgments about those effects most relevant to the assessment of human health. There are many different endpoints the hazard identification could cover, depending on the chemical considered. In order to maintain a consistent approach for all chemicals evaluated in this HHRA, the list of possible endpoints was condensed to include those thought to be most relevant to this evaluation for the TxDOT Roadside Pest Management Program. As such, the following endpoints were selected and qualitatively evaluated for each pesticide: mechanism of action; acute oral toxicity; chronic systemic toxic effects; effects on organ systems; reproductive and teratogenic effects; carcinogenicity and mutagenicity; irritation and sensitization (effects on skin and eyes); systemic toxic effects from dermal exposure; and inhalation exposure. Acute toxicity and chronic systemic toxic effects are addressed in Section 4.3, Dose-Response Assessment.

Many scientific studies are available from which to obtain data. This characterization was primarily based on toxicity information identified from toxicity profiles and HHRAs completed for Pesticide Tolerance regulations published in the USEPA Federal Register, as well as Registration Eligibility Decisions (REDs) and pesticide fact sheets completed by the USEPA Office of Pesticide Programs. USEPA was used as the primary source because of its reliance on approved scientific studies from which it gathers evidence to establish pesticide tolerances (in or on food) and toxicity criteria for

use in agricultural and non-agricultural settings. Other literature sources, including but not limited to the chemical manufacturers, approved scientific studies, pesticide databases, and the USDA Forest Service were consulted when USEPA-based information was not available.

The results of the hazard identification for each chemical active ingredient are summarized in **Table 4-1**. Due to the large number of chemicals evaluated in this HHRA, discussion of hazard identification results are limited to those pesticide/property combinations that displayed potential for adverse health effects.

4.1.1 Teratogenicity

Of the 12 active ingredients for the chemical products used by TxDOT, only clopyralid showed evidence of teratogenicity. However, as stated in **Table 4-1**, birth defects in test animals were only seen at greatly exaggerated doses. No birth defects were observed at doses several times greater than those expected from normal exposure. As summarized in the Pesticide Tolerance for Clopyralid (USEPA, 2002a), in the two generation reproduction study, offspring toxicity, characterized as decreased pup weight and increased liver weights, occurred only at the highest dose tested (1,500 mg/kg/day), which is higher than the limit dose (1,000 mg/kg/day). These changes occurred in the presence of severe parental toxicity (decreased body weight, body weight gain, food consumption, and slight focal hyperkeratosis of the gastric mucosa). In the developmental rabbit study, hydrocephalus was seen in eight fetuses (3/15 litters) only at the highest dose tested (250 mg/kg/day) in the presence of severe maternal toxicity that manifested as death, decreases in mean body weight and lesions of the gastric mucosa; the developmental NOAEL was 110 mg/kg/day. However, based on the results of the studies, the USEPA determined that an additional safety factor was not necessary because in general, fetal effects were only seen in the presence of maternal toxicity and because the existing toxicology database, which is complete, revealed no quantitative or qualitative evidence of increased susceptibility following *in utero* exposure to rats and rabbits and/or following prenatal/postnatal exposure to rats (USEPA, 2002a).

TABLE 4-1
SUMMARY OF HAZARD IDENTIFICATION FOR PESTICIDE ACTIVE INGREDIENTS

Active Ingredient	Trade Name	Mechanism of Action		Teratogenicity		Carcinogenicity		Mutagenicity		Genotoxicity		Eye Irritant		Skin Irritant		Dermal Sensitization		Inhalation	
Clopyralid	Transline	Pyridine family, auxin mimic	(3)	Birth defects in test animals only at greatly exaggerated doses. No birth defects observed at doses several times greater than those expected from normal exposure.	(10)	Acceptable oral rat and mouse carcinogenicity studies show no evidence of carcinogenic or mutagenic potential.	(9)	Acceptable oral rat and mouse carcinogenicity studies show no evidence of carcinogenic or mutagenic potential.	(9)	Negative. Ames bacterial mutagenicity assay; Host-Mediated assay In vivo cytogenetic test, rat; In vivo cytogenetic test, mouse; In vivo dominant lethal test, rat; In vitro unscheduled DNA synthesis assay in primary rat hepatocyte cultures; In vitro mammalian cell gene mutations assay in Chinese hamster ovary cell cultures.	(11)	Yes	(10)	Yes	(10)	No	(11)	No	(11)
Fenoxycarb	Award	Insect growth regulator	(2)	No effects observed.	(12)	Group B2 carcinogen based on lung carcinomas and Hardeian gland carcinomas in mice.	(13)	No effects observed.	(12)	No effects observed.	(12)	Slightly irritating (Rabbit study)	(12), (14)	Non-irritating (Rabbit study)	(12), (14)	No (Guinea pig study)	(12)	No	(13)
Fluroxypyr	Vista	Auxin mimic	(4)	No adverse effect evident.	(15)	No adverse effect indicated.	(15)	No adverse effect evident.	(15)	Negative. Short-term assays for genotoxicity consisting of an in vitro assay for cytogenetic damage using the Chinese hamster ovary cells, an in vitro chromosomal aberration assay, and an in vivo cytogenetic assay in the mouse bone marrow (micronucleus test).	(16)	Moderate eye irritation	(17)	Non-irritating (Guinea pig study)	(17)	Did not exhibit sensitization potential (Guinea pig study).	(18)	No risk from exposure	(16)
Glyphosate	Round up Pro & Aquamaster	Inhibits amino acid synthesis	(1)	No evidence based results of two multigenerational rat reproduction studies and developmental toxicity studies in rats and rabbits.	(19)	Group E - No evidence of carcinogenicity. No treatment-related tumors at any dose level tested up to the limit in rats or mice, and lack of evidence of mutagenicity/ genotoxicity.	(19)	Negative based on gene mutation assays in S. typhimurium and E. coli WP2hcrA strains, Chinese hamster ovary (CHO) cells/HGPRT.	(19)	No effects observed.	(19)	Yes	(19)	Mild or slight.	(19)	No	(19)	No	(19)
Imazapyr	Habitat	Inhibits amino acid synthesis	(3)	No evidence based results of two multigenerational rat reproduction studies and developmental toxicity studies in rats and rabbits.	(20)	Group E - No evidence of carcinogenicity. Two year rat feeding study.	(21)	Negative based on bacterial reverse mutation (Ames Assay), in vitro mammalian cell gene mutation, in vitro mammalian chromosome aberration (CHO).	(21)	Negative. No genotoxic activity in acceptable in vitro tests.	(20)	Yes	(21)	Non-irritating to slight erythema and edema.	(21)	No	(21)	Slightly toxic	(20)
Methoprene	Altosid XR	Insect growth regulator	(2)	No evidence based on results of three generation rat reproduction study, mouse, and rabbit gestational studies.	(22)	No evidence based on 2-year rat feeding study, 18-month mouse feeding study.	(22)	No evidence based on bacterial assay and dominant lethal study.	(22)	Negative for reverse mutation S. typhimurium and chromosomal aberrations in CHO cells.	(23)	Mild, moderate (Rabbit study)	(24)	No (Rabbit study)	(24)	No (Guinea pig study)	(24)	No	(22)
Metsulfuron methyl	Escort XP	Inhibition of cell division in rapidly growing tips of roots and shoots by inhibition of amino acid synthesis	(5)	Negative for developmental abnormalities to offspring of rats and rabbits fed 1000 mg/kg/day and 700 mg/kg/day respectively during gestation (IRIS 1995).	(5)	Group E - No evidence of carcinogenicity. Two year rat feeding study.	(25)	Negative based on acceptable tests to measure mutagenicity.	(5)	Negative based on acceptable tests to measure mutagenicity.	(5)	Moderate eye irritation (Rabbit study)	(5)	Mild (Guinea pig study)	(5)	No (Guinea pig study)	(5)	No	(5)

TABLE 4-1
SUMMARY OF HAZARD IDENTIFICATION FOR PESTICIDE ACTIVE INGREDIENTS

Active Ingredient	Trade Name	Mechanism of Action		Teratogenicity		Carcinogenicity		Mutagenicity		Genotoxicity		Eye Irritant		Skin Irritant		Dermal Sensitization		Inhalation	
Sulfometuron methyl	Oust XP	inhibition of acetolactate synthase	(6)	No birth defects were noted in one rat study and two rabbit studies; mothers fed up to 750 mg/kg. Rats fed 250 mg/kg in their diets exhibited lower maternal and fetal body weights.	(5)	No carcinogenic effects detected in either rats or mice at low to moderate doses.	(5)	Negative in variety of tests conducted on Salmonella cells and CHO cells.	(5)	Negative in variety of tests conducted on Salmonella cells and CHO cells.	(5)	Yes. Usually clears within several days.	(5)	No	(5)	No	(5)	Slightly toxic	(5)
Sulfosulfuron	Outrider	inhibition of acetolactate synthase	(7)	Negative based on results of 2-generation reproduction study in the rat.	(5)	Likely human carcinogen based on (1) occurrence of rare transitional cell papilloma and carcinoma of the urinary bladder in female rats; (2) occurrence of rare benign mesenchymal tumors of the urinary bladder in male as well as one renal adenoma in both male and female mice.	(26)	Negative outcome in following studies: gene mutation bacterial reverse gene mutation with Salmonella; an in vitro mammalian forward gene mutation with CHO cells; in vitro chromosome aberration study on human lymphocytes; and an in vivo structural chromosome aberration micronucleus test	(26)	Negative outcome in following studies: gene mutation bacterial reverse gene mutation with Salmonella; an in vitro mammalian forward gene mutation with CHO cells; in vitro chromosome aberration study on human lymphocytes; and an in vivo structural chromosome aberration micronucleus test	(26)	Moderate (Rabbit study)	(27)	No (Rabbit study)	(27)	No (Guinea pig study)	(27)	Low	(26)
Triclopyr	Pathfinder II & Garlon	Pyridine family, auxin mimic	(3)	Rat study-mild fetotoxicity, but no birth defects; no teratogenic effects in rabbits treated in a similar manner. Evidence suggests that the human risk of birth defects is fairly low due to chronic exposure to triclopyr.	(5)	No evidence based on 2-year rat and mouse feeding studies.	(28)	Negative in Ames assays, dominant lethal assay, and tests conducted on Salmonella cells.	(28)	Negative in Ames assays, dominant lethal assay, and tests conducted on Salmonella cells.	(28)	TEA-corrosive; BEE-moderate	(28)	Minimal-TEA and BEE	(28)	Yes-TEA and BEE (Guinea pig study)	(28)	Low	(28)
Sulfometuron methyl	Landmark MP	see above		see above		see above		see above		see above		see above		see above		see above		see above	
Chlorsulfuron (telar)		inhibition of acetolactate synthase	(6)	Negative based on results of 3-generation reproduction study in the rat.	(29)	No evidence based on 2-year rat and mouse feeding studies.	(29)	No evidence of chromosomal aberrations.	(29)	No evidence of chromosomal aberrations.	(29)	Moderate (Rabbit study)	(30)	Mild (Rabbit study)	(30)	No	(30)	Not likely	(30)
Amino pyralid	Milestone VM	Pyridine family, auxin mimic	(8)	Reproductive studies with rats and rabbits show not teratogenic nor will it interfere with in utero development.	(31)	Not likely to be a carcinogen.	(32)	Negative based on short-term assays consisting of a bacterial reverse mutation assay (Ames test), an in vitro assay for cytogenetic damage using the Chinese hamster ovary cells, an in vitro chromosomal aberration assay using rat lymphocytes, and an in vitro cytogenetic assay in the mouse bone marrow (micronucleus test).	(31)	Negative based on short-term assays consisting of a bacterial reverse mutation assay (Ames test), an in vitro assay for cytogenetic damage using the Chinese hamster ovary cells, an in vitro chromosomal aberration assay using rat lymphocytes, and an in vitro cytogenetic assay in the mouse bone marrow (micronucleus test).	(31)	Yes (Rabbit study)	(31)	No (Rabbit study)	(31)	No(Guinea pig study)	(31)	Low	(31)

TABLE 4-1
SUMMARY OF HAZARD IDENTIFICATION FOR PESTICIDE ACTIVE INGREDIENTS

Active Ingredient	Trade Name	Mechanism of Action		Teratogenicity		Carcinogenicity		Mutagenicity		Genotoxicity		Eye Irritant		Skin Irritant		Dermal Sensitization		Inhalation	

Notes:
auxin - plant growth hormone
BEE - butoxyethyl ester
TEA - triethylamine
CHO - Chinese hamster ovaries

References:
(1) http://weedeco.msu.montana.edu/class/LRES443/specific_information_on_herbicid.htm
(2) http://ipcm.wisc.edu/programs/school/appendix/pesticides.htm
(3) http://tncweeds.ucdavis.edu/products/handbook/08.HerbicideProperties.pdf
(4) http://www.epa.gov/opprd001/factsheets/fluroxypyr.pdf
(5) Pesticide Information Profile, 1993 (http://pmep.cce.cornell.edu/profiles/)
(6) http://weeds.montana.edu/weedphys/differential.pdf
(7) http://www.oznet.ksu.edu/library/crpsl2/c715.pdf
(8) Dow AgroSciences, 2005
(9) http://www.epa.gov/fedrgstr/EPA-PEST/2002/September/Day-25/p24232.htm
(10) Product MSDS, C&P Press, 2005
(11) http://www.epa.gov/fedrgstr/EPA-PEST/1997/July/Day-11/p18256.htm
(12) Product MSDS, Syngenta, 2002
(13) http://www.epa.gov/fedrgstr/EPA-PEST/1997/April/Day-25/p10749.htm
(14) http://www.beyondpesticides.org/infoservices/pesticidefactsheets/toxic/fenoxycarb.htm
(15) http://www.cdpr.ca.gov/docs/toxsums/pdfs/5768.pdf
(16) http://www.epa.gov/EPA-PEST/2003/January/Day-15/p848.htm
(17) Product MSDS, Dow AgroScience, 2004
(18) http://www.epa.gov/opprd001/factsheets/fluroxypyr.pdf
(19) http://www.epa.gov/fedrgstr/EPA-PEST/2002/September/Day-27/p24488.htm
(20) http://pmep.cce.cornell.edu/profiles/herb-growthreg/fatty-alcohol-monuron/imazapyr/imazapyr.html
(21) http://www.epa.gov/EPA-PEST/2003/September/Day-26/p24123.htm
(22) http://www.epa.gov/REDs/old_reds/methoprene.pdf
(23) http://www.inchem.org/documents/jmpr/jmpmono/2001pr09.htm#2.2.4
(24) Product MSDS, Zoecon, 1997
(25) http://www.epa.gov/EPA-PEST/1999/December/Day-16/p32652.htm
(26) http://www.epa.gov/EPA-PEST/1999/May/Day-19/p12247.htm
(27) http://kingtaichem.com/pro_h_SULFOSULFURON.htm
(28) http://www.epa.gov/oppsrrd1/REDs/2710red.pdf
(29) http://www.epa.gov/EPA-PEST/2002/August/Day-14/p20229.htm
(30) Product MSDS, Dupont, 2004.
(31) http://www.epa.gov/fedrgstr/EPA-PEST/2004/June/Day-02/p12020.htm
(32) http://www.epa.gov/fedrgstr/EPA-PEST/2005/August/Day-10/p15523.htm

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4.1.2 Carcinogenicity

Of the 12 active ingredients for the pesticide products used by TxDOT, fenoxycarb and sulfosulfuron showed evidence of carcinogenicity in acceptable animal studies. However, in each case, carcinogenic effects are not expected to be seen in humans. In addition, carcinogenic risk estimates were calculated by the USEPA and as such, quantitative assessments of carcinogenic risk were not performed for these chemicals. The following paragraphs provide the rationale for this.

Fenoxycarb was classified as a Group B2 carcinogen by the USEPA's Cancer Peer Review Committee based on lung carcinomas and Hardeian gland carcinomas in mice (USEPA, 1997b). For the purpose of the Pesticide Tolerance for Emergency Exemptions for Fenoxycarb (USEPA, 1997b), the Cancer Peer Review Committee recommended calculating cancer risk estimates using a linear low-dose approach. A dietary (food only) cancer risk assessment was calculated for the United States population and was adjusted for the duration of exposure of 5 years over a 70 year lifetime. The total carcinogenic risk (food only) was calculated at 4.9×10^{-08}, which is well below USEPA's lower limit for carcinogenic risk of 1×10^{-06}. Fenoxycarb is registered for use on lawns, turf, pets, and inside domestic dwellings. USEPA, at this time, does not have exposure data with which to determine risk from these non-dietary, non-occupational uses. However, in the best scientific judgment of the USEPA, chronic exposure to fenoxycarb residues resulting from potential residential and/or water exposure would not increase the total cancer risk so that it exceeds the USEPA's LOC. The USEPA concluded that in its best scientific judgment, chronic exposure to fenoxycarb residues resulting from potential residential and/or water exposure would not increase the total cancer risk so that it exceeds the USEPA's LOC.

Sulfosulfuron was classified by the USEPA's Cancer Assessment Review Committee as a likely human carcinogen based on the following weights-of-evidence: 1) occurrence of rare transitional cell papilloma and carcinoma of the urinary bladder in female rats; 2) occurrence of rare benign mesenchymal tumors of the urinary bladder in male, as well as one renal adenoma in both male and female mice; and 3) the relevancy of the observed tumors to human exposures. The USEPA subsequently conducted risk assessments to assess exposures from sulfosulfuron for the Pesticide Tolerance for Sulfosulfuron (USEPA, 1999). The USEPA performed a cancer exposure analysis using tolerance level residues and 100 percent crop treated information to estimate the lifetime cancer risk for the general population (USEPA, 1999). The lifetime risks

calculated for infants, children (1 to 6 years), and children (7 to 12 years) were well below USEPA's lower limit for carcinogenic risk of 1×10^{-06}. A risk assessment from non-dietary exposure (i.e., post-application exposure to sulfosulfuron on turf at playgrounds, parks and residential areas) was also conducted (USEPA, 1999), resulting in no unacceptable cancer risks. Finally, an aggregate cancer risk (includes food, water, and post-application exposure) for the United States population was calculated as part of the Pesticide Tolerance application. Based on this, USEPA concluded that there is reasonable certainty that no harm will result from aggregate exposure to sulfosulfuron residues. Therefore, it was concluded that the cancer dietary risk associated with sulfosulfuron was below the USEPA's LOC.

Furthermore, Monsanto, the manufacturer of sulfosulfuron, has conducted its own review of the data, which was used by the USEPA to classify this chemical as a likely human carcinogen. Monsanto states that sulfosulfuron does not pose a significant carcinogenic risk to humans when used in accordance with product labels (Monsanto, 2005). Based on the findings of published scientific studies, the single occurrence of the mouse kidney adenomas at the highest dose tested is not considered suggestive of a chemical effect (Hard, 2000, as cited in Monsanto, 2005) and the male mouse bladder tumors were unique to the strain of mouse tested and are not considered relevant (Halliwell, 1998 and International Life Sciences Institute, 1997, as cited in Monsanto, 2005). Urinary bladder tumors in the rats were observed only in the presence of calcified stones that formed in the urine and consisted almost entirely of sulfosulfuron. These stones irritated the cells lining the urinary tract, resulting in an abnormal increase in cell numbers, which subsequently lead to the formation of tumors. This is a well-known mode of action in rats that has also been demonstrated for other non-genotoxic chemicals due to the anatomy of their urinary tract (Rodent Bladder Carcinogenesis Working Group, 1995, as cited in Monsanto, 2005). In addition, more recent data exist confirming this mode of action (Cohen et al., 2002, as cited in Monsanto, 2005). Finally, sulfosulfuron is not considered a human carcinogen by regulatory agencies in Canada, Australia, England, or Ireland (Monsanto, 2005). For these reasons, Monsanto expects the USEPA to change its cancer classification for sulfosulfuron once it completes its review of the mechanistic data (Monsanto, 2005).

4.1.3 Eye and Skin Irritation

In most cases, the active ingredients in the pesticides used by TxDOT were found to be eye and skin irritants. Specifically, as shown on **Table 4-1**, all chemicals were eye

irritants at some level of mild to corrosive. Those chemicals identified as skin irritants were only mildly irritating. However, these findings were based on results of animal tests and if product label instructions are properly followed, eye and skin irritation are not expected to occur.

4.1.4 Inhalation

As summarized on **Table 4-1**, imazapyr, sulfometuron methyl, sulfosulfuron, triclopyr, and amino pyralid showed low levels of toxicity via inhalation. However, if these findings were based on results of animal tests and if product label instructions are properly followed, adverse health effects would be minimal. Finally, none of the pesticide active ingredients were found to be mutagenic, genotoxic or dermal sensitizers.

4.2 EXPOSURE ASSESSMENT

The exposure assessment estimates the magnitude of actual and/or potential human exposure, the frequency and duration of those exposures, and the pathways (i.e., inhalation, ingestion, and dermal contact) by which people are potentially exposed. This section identifies the exposure scenarios evaluated in this HHRA for the pesticides used by TxDOT in its Roadside Pest Management Program. Exposure assessments are conducted for both pesticide application workers (workers) and members of the general public for each pesticide listed in Section 2.0 at the specific application rates provided in Section 2.0.

4.2.1 Potential Human Receptors

Specifically, the following human exposure receptors and exposure pathways were quantitatively evaluated in this HHRA for the pesticides used by TxDOT in its Roadside Pest Management Program. These exposure scenarios are presented in more detail in Section 4.2.3.

<u>Worker</u>

- General exposure; and
- Accidental/incidental dermal contact.

<u>General Public</u>

- Adult and child, accidental direct spray dermal contact;

- Adult and child, dermal contact with contaminated vegetation;
- Adult and child, ingestion of contaminated fruit;
- Adult and child, ingestion of contaminated water; and
- Adult and child, ingestion of contaminated fish.

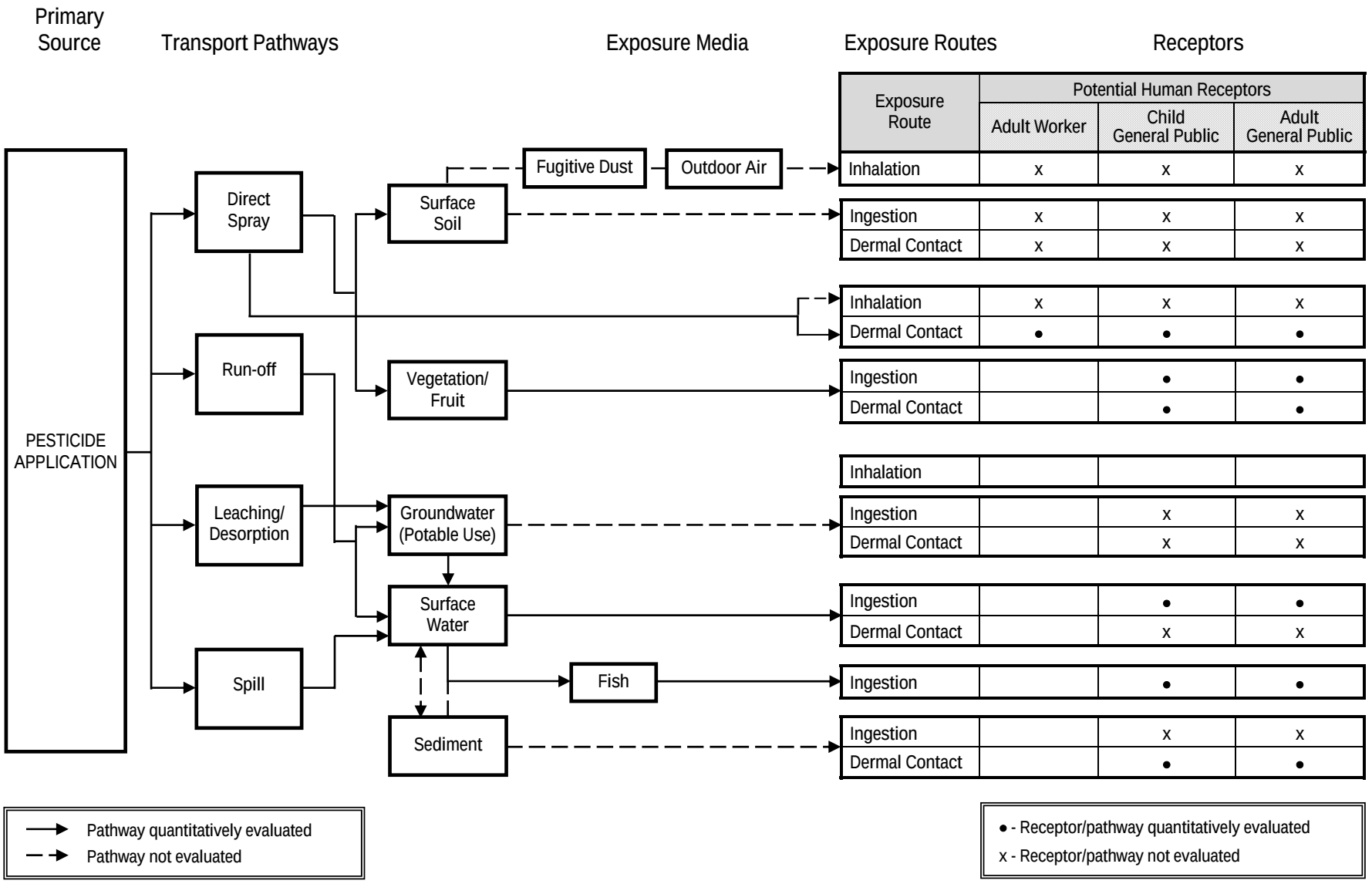
4.2.2 Conceptual Site Model

Development of a conceptual site model of potential exposure is critical in evaluating exposures for the human receptors. The conceptual site model considers all reasonable potential exposures. Potential exposure scenarios for pesticides listed in Section 2.0 are summarized in the conceptual site model in **Figure 4-1** of this HHRA.

Figure 4-1 presents an overview of all exposure scenarios considered for the chemicals evaluated in this HHRA. However, the potential exposure pathways identified in **Figure 4-1** do not apply to all chemicals used or planned for use by TxDOT in its Roadside Pest Management Program, specifically methoprene (Altosid XR), triclopyr-BEE (Pathfinder II), and glyphosate-isopropylamine salt (Aquamaster). The rationale for excluding these chemicals from evaluation by a particular scenario is provided in the following paragraph.

Altosid XR (methoprene), a juvenile insect growth regulator used for mosquito control, is a solid (briquette) added directly to surface water. Therefore, direct spray/spray drift deposition onto non-target vegetation, direct spray/spray drift deposition onto surface soil, overland transport with surface soil via surface runoff to down-gradient surface soil, surface water, and sediment, and leaching of chemicals from surface soil by infiltrating precipitation and transport to surface water and sediment with groundwater are considered incomplete transport pathways. These same transport pathways are also considered incomplete for Pathfinder II (triclopyr-BEE) and Aquamaster (glyphosate-isopropylamine salt). Pathfinder II is applied directly to terrestrial vegetation (basal bark treatments) using backpack sprayers, while Aquamaster is applied directly to aquatic vegetation (i.e., emergent vegetation, including cattails and giant reed) using handgun sprayers.

FIGURE 4-1: HUMAN HEALTH CONCEPTUAL MODEL



Since the application of these chemicals are applied directly to target vegetation using either a backpack sprayer (Pathfinder II) or a handgun sprayer (Aquamaster), direct spray/spray drift deposition onto non-target receptors/biota would not be expected. Direct spray/spray drift deposition onto surface soil also is unlikely when basal bark treatments or direct foliar applications to aquatic vegetation are used; therefore, migration with surface soil via surface runoff to down-gradient soil/sediment and migration with groundwater to down-gradient surface water and sediment are considered incomplete transport pathways in this HHRA.

4.2.3 Quantification of Exposure

The equations for estimating exposure rates due to direct exposures to chemicals used by TxDOT in its Roadside Pest Management Program for the various identified pathways are presented in Section 4.2.3.1. The chemicals evaluated by each scenario are also identified. The exclusion of a given chemical from evaluation by a particular scenario is based on the conceptual model discussed in Section 4.2.2.

4.2.3.1 Workers

Two types of exposure assessments were considered for workers: general and accidental/incidental. The term "general" indicates those exposures that involve estimates of absorbed dose based on the handling of a specified amount of a chemical during specific types of applications. "Accidental/incidental" exposure scenarios involve specific types of events that could occur during any type of application.

Worker exposure rates are expressed in units of milligram of absorbed dose per kilogram of body weight (mg/kg-body weight) per pound of chemical handled. Default exposure rates were estimated for two different types of application methods: directed foliar (backpack) and boom-spray (hydraulic ground spray).

General Exposures

An exposure assessment was evaluated for a worker under a general exposure scenario. This scenario is based on estimated absorbed dose in workers and the amounts of the chemical handled by the workers. Default exposure rates were estimated for two different types of application methods: directed foliar (backpack) and boom-spray (hydraulic ground spray). The computational details for each general exposure assessment for workers are provided in human health exposure assessment worksheets contained in Volume II, Appendix D for all chemicals except Altosid XR,

Pathfinder II (boom spray), and Aquamaster (boom spray). For the given chemical the absorbed dose was (mg/kg-body weight) estimated by **Equation 4-1**:

$$AD_x = (AHD_x)(ADR_x)$$

where AD_x is the amount of chemical x absorbed (mg/kg-body weight), AHD_x is the amount of chemical x handled per day, and ADR_x is the absorbed dose rate of chemical x handled per day.

The amount of chemical absorbed by the worker was calculated by **Equation 4-1a**:

$$AHD_x = (R_x)(ATD_x)$$

where R_x is the application rate of chemical x and ATD_x is acres treated per day. Application rates evaluated for each chemical are those identified previously in Section 2.0.

The number of acres treated per day was calculated by **Equation 4-1b**:

$$ATD_x = (Hrs_x)(acres_x)$$

where Hrs_x is the number of hours of application per day and $acres_x$ is the number of acres treated per hour for chemical x. Hours of application per day and number of acres treated per hour for each chemical are those identified previously in Section 2.0.

Accidental Exposures

Typical occupational exposures may involve multiple routes of exposure (i.e., oral, dermal, and inhalation). However, dermal exposure is considered the predominant route for chemical applicators for this HHRA. Typical multi-route exposures are covered by the methods used previously on general worker exposures. Accidental exposures are most likely to involve splashing a solution of chemicals onto the skin or to involve various dermal exposure scenarios. The two types of exposures modeled were those involving direct contact with a solution of the chemical and those associated with accidental spills of the chemical onto the surface of the skin. The computational details for each accidental exposure assessment for workers are provided in human health exposure assessment worksheets contained in Volume II, Appendix D for all pesticides except Altosid XR, Pathfinder II (boom spray), and Aquamaster (boom spray).

Exposure scenarios involving direct contact with solutions of the chemical are characterized by immersion of the hands for one minute or wearing contaminated gloves for one hour. It is assumed that contamination of gloves or other clothing is possible and that wearing gloves grossly contaminated with a chemical solution is equivalent to immersing the hands in a solution. For the given pesticide, the absorbed doses (mg/kg-body weight) for a worker wearing contaminated gloves for one minute and one hour were estimated by **Equation 4-2**:

$$AD_x = \frac{(C_x)(Kp_x)(SA)(t)}{BW}$$

where AD_x is the amount of chemical x absorbed (mg/kg-body weight), C_x is the concentration of chemical x in solution (mg/mL), Kp_x is the dermal permeability constant for chemical x (cm/hr), SA is the exposed surface area (cm^2), t is the amount of time exposed (hours) and BW is body weight (kg).

Exposure scenarios involving pesticide spills onto the skin were characterized by a spill onto the lower legs in addition to a spill onto the hands. For both scenarios, it was assumed that the contaminated skin is effectively cleaned after one hour. For a given chemical, the absorbed doses (mg/kg-body weight) for a worker accidentally spilling a chemical on the hands or legs for one hour were estimated by **Equation 4-3**:

$$AD_x = \frac{(Amnt_x)(Prop_x)}{BW}$$

where AD_x is the amount of chemical x absorbed (mg/kg-body weight), $Amnt_x$ is the amount of chemical x deposited on skin (mg), $Prop_x$ is the proportion of chemical x absorbed over time t ($hour^{-1}$), and BW is body weight (kg).

The amount of chemical x deposited on skin (mg) was calculated by **Equation 4-3a**:

$$Amnt_x = (L_x)(C_x)(SA)$$

where L_x is the amount of chemical x solution adhering to skin after a spill or direct spray (mL/cm^2), C_x is the concentration of chemical x in solution (mg/mL), and SA is the exposed surface area (cm^2).

The proportion of chemical x absorbed over time t (hour^{-1}) was calculated by **Equation 4-3b**:

$$Prop_x = 1 - \exp(-k_{ax}t)$$

where k_{ax} is the dermal absorption rate of chemical x (hour^{-1}) and t is the duration of time exposed (hours).

4.2.3.2 General Public

Under normal conditions, members of the general public should not be exposed to substantial levels of chemicals used for roadside pest management. However, several scenarios were evaluated for this HHRA that should adequately estimate exposures such that risks are likely to be over-estimated rather than under-estimated.

The two types of exposure scenarios evaluated for the general public include acute exposure and chronic exposure. The acute exposure scenarios were primarily accidental, assuming an individual is exposed either during or shortly after application. Specific scenarios were considered for direct spray, including dermal contact with contaminated vegetation, and consumption of contaminated fruit and water. The chronic exposure scenarios parallel the acute exposure scenarios but were based on longer periods of exposure after application. Consumption of contaminated fruit, water, and fish were evaluated as chronic exposure scenarios. Ingestion of contaminated fish was not evaluated as an acute exposure. In general, residues in fish will not reach sufficient levels to cause significant exposures over short time scales.

The chemicals evaluated by each scenario are identified in the following paragraphs. The exclusion of a given chemical from evaluation by a particular scenario is based on the conceptual model discussed in Section 4.2.2.

Acute Exposures

Direct Contact with Pesticides via Direct Spray

Direct sprays involving ground applications (backpack or boom spray) were modeled similar to accidental spills for workers. For these scenarios, it was assumed that the individual is sprayed with the pesticide solution and that an amount of the solution remains on the skin and is absorbed. Two receptors were evaluated under these scenarios: a young child (assuming exposure of 100 percent coverage of the surface area of the body) and a female adult (assuming exposure of lower legs). **Equations 4-3,**

4-3a, and 4-3b were used to calculate absorbed dose for these exposure scenarios. The computational details for each direct spray exposure assessment for the general public are provided in human health exposure assessment worksheets included in Volume II, Appendix D for all chemicals except Altosid XR, Pathfinder II, and Aquamaster.

Dermal Contact with Contaminated Vegetation

Two acute exposure assessments for general public were evaluated under a dermal contact with contaminated vegetation scenario. This exposure scenario assumes the chemical is sprayed at a given application rate and that a female adult and a young child come in contact with sprayed vegetation or other contaminated surfaces at some period after the spray operations. It also assumes a contact period of one hour and that the chemical is not effectively removed by washing for 24 hours. The computational details for each dermal contact with contaminated vegetation exposure assessment for the general public are provided in human health exposure assessment worksheets included in Volume II, Appendix D for all chemicals except Altosid XR, Pathfinder II, and Aquamaster. For the given chemical, the absorbed dose (mg/kg-body weight) is estimated by **Equation 4-4**:

$$AD_x = \frac{(Amnt_x)(PropAbs_x)}{BW}$$

where AD_x is the amount of chemical x absorbed (mg/kg-body weight), $Amnt_x$ is the amount of chemical x transferred to skin surface (mg), $PropAbs_x$ is the proportion of chemical x absorbed over time t_e (unitless), and BW is body weight (kg).

The amount of chemical x transferred to skin surface (mg) was calculated by **Equation 4-4a**:

$$Amnt_x = (Tr)(t_c)(SA)$$

where Tr is the transfer rate of chemical x (mg/cm^2-hr), t_c is the contact time (hours), and SA is the exposed surface area (cm^2).

The transfer rate of chemical x (mg/cm^2-hr) was calculated by **Equation 4-4b**:

$$Tr = \frac{10^{(1.09x\log 10(Dr)+0.05)}}{1000\mu g/mg}$$

where Dr_x is the dislodgeable residue (lb/acre) of chemical x. The dislodgeable residue (Dr) of chemical x (lb/acre) was calculated by **Equation 4-4c**:

$$Dr_x = (R\mu g_x)(PropDr_x)$$

where $R\mu g_x$ (lb/acre) is the application rate of chemical x in lb/acre multiplied by a constant, $PropDr_x$, or the proportion of chemical x that is dislodgeable.

The proportion of chemical x absorbed over time t_e (unitless) was calculated by **Equation 4-4d**:

$$PropAbs_x = 1 - \exp(-k_{a\,x} t_e)$$

where t_e is the exposure time in hours.

Ingestion of Contaminated Fruit

Two acute exposure assessments for general public were evaluated under an ingestion of contaminated fruit scenario. It is assumed that individuals could consume vegetation contaminated with pesticides applied by TxDOT. For this HHRA, consumption of contaminated fruit by an adult male and a child after treatment of an area in which wild fruit grow was evaluated as an exposure scenario. For the acute exposure scenario, the estimated residue level was taken as the product of the application rate and residue rate. The computational details for each ingestion of contaminated fruit exposure assessment for the general public are provided in human health exposure assessment worksheets included in Volume II, Appendix D for all pesticides except Altosid XR, Pathfinder II, and Aquamaster. For the given chemical, the dose (mg/kg-body weight) was estimated by **Equation 4-5**:

$$D_x = (A)(C_x)$$

where A is the amount of fruit consumed per unit body weight (kg fruit/kg body weight/day) and C_x is the concentration of chemical x on fruit (mg/kg fruit).

The concentration of chemical x on fruit (mg/kg fruit) was calculated by **Equation 4-5a**:

$$C_x = (R_x)(rr_x)(Drift_d)(1 - wash)$$

where R_x is the application rate of chemical x (lb/acre), rr_x is the residue rate of chemical x (mg/kg per lb/acre), $Drift_d$ is the proportion of the on-site application rate

that drifts off-site to a distance *d* due to physical processes (unitless; derived using the AgDRIFT model), and *wash* is the proportion removed by washing (unitless). Note that no washing is assumed for this scenario, and no dissipation is assumed for the on-site acute exposure. Therefore, $Drift_d$ equals 1.0.

Ingestion of Contaminated Water

One acute exposure assessment for general public was evaluated under an ingestion of contaminated water scenario: consumption of contaminated water by a young child from a pond following an accidental spill. This scenario was based on the assumption that exposure occurs shortly after the spill, and no dissipation or degradation of the pesticide was considered. The computational details for the acute ingestion of contaminated water for the general public are provided in the human health exposure assessment worksheet included in Volume II, Appendix D for all pesticides except Altosid XR. For the given chemical, the dose (mg/kg-body weight) was estimated by **Equation 4-6**:

$$D_x = \frac{(A)(C_x)}{BW}$$

where A is the amount of water consumed per day (L/day), C_x is the concentration of chemical x in water (mg/L), and BW is body weight (kg).

For the accidental spill assessment, the concentration of chemical x in water (mg/L) was calculated by **Equation 4-6a**:

$$C_x = \frac{(VS_x)(C_{FLDx})}{VL}$$

where VS_x is the spill volume of the field solution (liters), C_{FLDx} is the concentration of chemical x in the field solution (mg/L), and VL is the volume of the pond (liters).

Chronic Exposures

Ingestion of Contaminated Fruit

Two chronic exposure assessments for the general public were evaluated under an ingestion of contaminated fruit scenario: 1) adult male; and 2) young child. This exposure scenario is the same as that considered for the acute scenario except that degradation and drift were considered in the calculations. For the chronic exposure

scenario, an exposure duration of 90 days was used. This represents the consumption of contaminated fruit that might be available over one growing season. In addition, a time-weighted concentration of a given chemical on fruit was calculated. Drift onto off-site vegetation at 25 feet from the point of application was estimated using AgDRIFT.

AgDRIFT is a model that provides estimates of drift based on general types of chemical applications (aerial and ground [low-boom spray, high-boom spray], and orchard blast. For the fruit scenario, low-boom, ground-spray with a droplet size of very fine-to-fine, and a wind speed of 5 mph at the point of application were modeled. Section 3.3.1.2 provides additional details of AGDRIFT. **Table 3-4** summarizes drift estimates for each chemical and associated application rate(s).

The computational details for the chronic ingestion of contaminated fruit for the general public are provided in the human health exposure assessment worksheets included in Volume II, Appendix D for all chemicals except Altosid XR, Pathfinder II, and Aquamaster. For the given chemical, the dose (mg/kg-body weight) was estimated by **Equation 4-7**:

$$D_x = (A)(C_{Con\,x})$$

where A is the amount of fruit consumed per unit body weight (kg fruit/kg body weight/day) and C_{Conx} is the time-weighted concentration of chemical x on fruit (mg/kg fruit). The initial concentration on fruit is calculated using **Equation 4-5a** and C_{Conx} is calculated using **Equations 3-20** and **3-21**. Note that washing would not be part of this equation but would be included in the calculation of C_{Conx}; however, as with the acute scenario, no washing was assumed.

Ingestion of Contaminated Water

Two chronic exposure assessments for the general public were evaluated under an ingestion of contaminated water scenario. The scenario for chronic exposure from contaminated water assumed that an adult male and a young child consume chemically contaminated water from a surface water body (i.e., a pond) for their entire lifetime.

The estimated concentrations in pond water were based on the modeled estimates from GLEAMS, with the exception of methoprene (Altosid XR) and glyphosate-isopropylamine salt (Aquamaster). The specific computational methods used to

estimate the concentration of each chemical in a hypothetical pond are presented and discussed in Section 3.3.1.2. The total mass of a given chemical entering the hypothetical pond on a yearly ($Mass_{xp}$) was derived by **Equation 3-22**. The concentration of a given chemical in pond surface water (C_{xsw}) was estimated by **Equation 3-23**.

As discussed in Section 3.3.1.2, the migration of applied pesticides was quantified using a web-based application NAPRA WWW of the GLEAMS Model Version 3.0. The web-based application examined the fate of chemicals in various soils under different meteorological and hydrogeological conditions. Outputs of NAPRA GLEAMS, expressed as yearly estimates of runoff volume per unit area (inches/hectare); groundwater volume per unit area (inches/hectare); mass of a chemical in surface runoff per unit area (mg/hectare); and mass of a chemical in groundwater per unit area (mg/hectare); were used to estimate the concentration of active ingredient in the off-site pond. A detailed description of the NAPRA GLEAMS model, input parameters and assumptions, as well as model outputs is presented in Baker (2006). The specific data used to estimate the concentration of a given chemical in pond surface water were dictated by the specific outputs generated by the NAPRA GLEAMS model.

The estimated dose (mg/kg-body weight) was calculated using **Equation 4-6**. The computational details for the chronic ingestion of contaminated water for the general public are provided in the human health exposure assessment worksheets included in Volume II, Appendix D for all pesticides except Pathfinder II.

Ingestion of Contaminated Fish

Four chronic exposure assessments for the general public were evaluated under an ingestion of contaminated water scenario. Exposures for two types of fishermen and children (for a total of four receptors) were estimated: 1) recreational; and 2) subsistence. This chronic exposure scenario was based on the assumption that an adult angler and child consume fish taken from chemically contaminated water where concentrations of a given chemical in ambient water were estimated based on GLEAMS modeling (identical to the concentrations used in the contaminated water by runoff/percolation scenarios). The computational details for the chronic ingestion of contaminated fish for the general public are provided in the human health exposure assessment worksheet included in Volume II, Appendix D for all chemicals except Pathfinder II. For the given chemical, the dose (mg/kg-body weight) was estimated by **Equation 4-8**:

$$D_x = \frac{(A)(Cfish_x)}{BW}$$

where A is the amount of fish consumed (kg/day), $Cfish_x$ is the concentration of chemical x in fish (mg/kg fish), and BW is body weight (kg). The concentration of chemical x in fish (mg/kg fish) was calculated using **Equation 4-8a**:

$$Cfish_x = (BCF)(C_{Wat\,x})$$

where BCF is the bioconcentration factor (L/kg fish) and C_{Watx} is the concentration of chemical x in water, which was calculated using **Equation 4-6a**. As a conservative measure, a whole-body BCF was used, which was calculated using **Equation 3-27**.

4.2.4 Exposure Parameters

The exposure parameters used in the estimation of potential dose from chemical (active ingredient only) exposure for each receptor are identified in the following paragraphs. USEPA promulgated exposure parameters were used when available. The Exposure Factors Handbook (USEPA, 1997c) was the primary resource for human health exposure parameters. When USEPA exposure parameters were not available, information from the USDA Forest Service (Forest Service) in conjunction with the document, *Preparation of Environmental Documentation and Risk Assessments* (SERA, 2001), was used to derive conservative values. The following paragraphs present the rationale for the selection of exposure factors for each receptor group evaluated in the HHRA.

4.2.4.1 Workers

Chemical applicators in TxDOT's program are likely to be the individuals who are most exposed to chemicals during the application process. Two general types of methods can be considered for worker exposure modeling, deposition-based and absorption-based (SERA, 2001). USEPA uses a deposition-based approach, which estimates the exposure dose from air concentrations and skin deposition monitoring data. The USDA Forest Service has generally used absorption-based models in which the amount of chemical absorbed is estimated from the amount of chemical handled. Absorption-based models are preferred by the Forest Service because dermal exposure appears to be the primary route of occupational exposure and studies that evaluated exposure routes indicated poor correlation between dermal deposition and chemical

absorption (SERA, 2001). This HHRA follows the Forest Service's absorption-based approach for estimating worker exposure as indicated in *Preparation of Environmental Documentation and Risk Assessments* (SERA, 2001).

General Exposures

In this HHRA, general exposures to workers were estimated based on occupational exposure rates established in SERA 2001 for two job activities: 1) directed foliar (or backpack application); and 2) broadcast foliar (or boom-spray). The absorbed dose rates used in the general worker exposure calculations are 0.01 mg/kg per lb/day for backpack application and 0.0009 mg/kg per lb/day for boom-spray. These values represent the upper limits of the ranges for absorbed dose rates defined in SERA 2001.

Descriptions of chemical applications provided by the USDA were used in this HHRA as default values for general workday parameters for both backpack application and boom-spray. A worker is assumed to treat on average 0.5 acre/hour and 11 acres/hour for backpack application and boom-spray, respectively (USDA, 1989). An average 8-hour workday was used in the calculations (typical workday of a TxDOT employee). In order to present a conservative yet plausible exposure assessment across all types of TxDOT chemical applicators, the average acres treated per hour values were selected rather than the upper limits provided by the USDA.

Accidental/Incidental Exposures

Dermal exposure was considered the predominant route of exposure for workers in this HHRA. The two types of accidental or incidental exposures that were modeled are those involving direct contact with a solution of the chemical and those associated with accidental spills of the chemical onto the surface of the skin. For purposes of this HHRA, an adult male has a body weight (BW) of 70 kg (USEPA, 1997c). A skin surface area of the hands (SA H) of 840 cm^2 (USEPA, 1997c) was used for the dermal exposure scenarios for worker wearing contaminated gloves for 1 minute and 1 hour and from an accidental spill to the hands. An average skin surface area of the lower legs (SA LL) of 2,070 cm^2 (USEPA, 1997c) was used for the dermal exposure scenarios for workers from an accidental spill to the lower legs.

Those dermal exposure scenarios involving immersion or contaminated clothes (i.e., wearing contaminated gloves for 1 minute and 1 hour) are most accurately modeled using Fick's first law, which requires an estimate of the permeability coefficient K_p

(cm/hour). For this HHRA, K_p for each chemical active ingredient was calculated using **Equation 4-9** from USEPA RAGS Part E (USEPA, 2004):

$$\log K_p = -2.80 + 0.66 \log K_{ow} - 0.0056MW$$

In this approach, K_p is estimated via an empirical correlation as a function of octanol/water partitioning coefficient (K_{ow}) and molecular weight (MW) obtained from an experimental database (the Flynn database composed of about 90 chemicals) of absorption of chemicals from water through human skin *in vitro* (USEPA, 2004). The previous equation can be used to predict the K_p of chemicals with K_{ow} and MW within an "Effective Prediction Domain" (EPD) as determined via statistical analysis based on the Flynn dataset provided in USEPA (2004). Chemicals with very large and very small K_{ow} values are outside of the EPD. Although large variances in some data points contributed to the definition of the EPD, it is defined primarily by the properties of the data used to develop the K_p equation. With no other data presently available for chemicals with very large and very small K_{ow}, USEPA (2004) recommends this equation as a means of estimating K_p (USEPA, 2004). The K_{ow} values and MWs were obtained from literature sources and are provided for each chemical as presented in Section 2.0.

Exposure scenarios involving chemical spills onto the skin assume a solution is spilled on to a given surface area of skin and that a certain amount adheres to the skin. This type of scenario is best characterized using first-order dermal absorption rates. First-order absorption assumes that the absorption rate is proportional to the concentration of the chemical at the absorption site. The following equation (**Equation 4-10**), provided in SERA 2001 for calculating first-order absorption rate coefficients (k_a), was used in this HHRA:

$$\log k_a = 0.233 \log K_{ow} - 0.00566MW - 1.49$$

The term, first-order, describes processes that occur in a fixed proportion relative to an instantaneous amount or concentration per unit time. As such, first-order rate coefficients are expressed in units of reciprocal time ($hour^{-1}$).

In accidental spill scenarios, the amount of liquid adhering to the surface of the skin must be calculated. The value of 8 mg/cm^2, as cited in SERA 2001, was used in this HHRA. This value represents the upper limit of the amount of liquid adhering to the surface of the skin from a study conducted by Mason and Johnson (1987) (as cited in SERA, 2001).

4.2.4.2 General Public

While it is highly unlikely that members of the general public would be exposed to substantial levels of chemicals under normal conditions associated with TxDOT's Pest Management Program, this HHRA conservatively evaluates several scenarios for this receptor group. As discussed previously, specific scenarios evaluated include direct spray, dermal contact with vegetation, and consumption of contaminated fruit, water, and fish.

These exposure scenarios require various estimates of body weight, surface area, and the consumption of contaminated food or water. These exposure parameters were taken primarily from USEPA (1997). The specific values are summarized and documented in the following paragraphs.

General Parameters

The body weights and skin surface areas used in this HHRA are taken from USEPA 1997. These values represent a consensus for common use. The body weight for a man used in this HHRA is 70 kg (USEPA, 1997c). This weight is currently used by USEPA as a standard composite body weight for males and females. A body weight (BW FA) of 64 kg is used for a woman (USEPA, 1997c), which represents an average body weight for a 25 to 35 year old woman. A body weight (BW C) of 15 kg is used for those exposure scenarios involving a child (USEPA, 1997c). This value is commonly used as a standard body weight for children from one to six years of age in HHRAs performed for the USEPA.

The following surface area estimates are also taken from USEPA 1997 for use in this HHRA. An average total body surface area (SA C) of 7,930 cm^2 was assumed for the child. An average total body surface area (SA FA) of 20,000 cm^2 and an average surface area (SA FA1) of 3,665 cm^2 for hands, arms, lower legs, and feet and 2,070 cm^2 for the lower legs were assumed for a female adult. In order to present conservative yet plausible exposure assessments across the receptors representing members of the general public, the average surface area values were selected rather than the upper limits provided by USEPA 1997.

Average fruit consumption of 3.4 g/day of fruit (USEPA, 1997c) was used for both adults and children. Average ingestion rates of 2.4 L/day and 1.5 L/day of water (USEPA, 1997c) were used for adults and children, respectively. An average ingestion rate of 8 g/day of fish (USEPA, 1997c) was used for both adult and children under a

recreational fishing scenario. An average ingestion rate of 70 g/day of fish (USEPA, 1997c) was used for both adult and children under a subsistence-fishing scenario. For the same reason as stated in the previous paragraph, the average ingestion rates were selected rather than the upper limits provided by USEPA 1997.

Direct Spray

In the conservative acute exposure scenarios, a young child is completely covered (i.e., 100 percent of body surface area is exposed) and an adult woman's lower legs are covered by direct spray of the chemical solution. These scenarios are intended to represent the upper bound of exposure. These scenarios are modeled similarly to accidental spills for workers. As with the direct spray worker exposure scenarios, k_a is estimated using **Equation 4-10** and 8 mg/cm^2 is the amount of chemical adhering to the skin.

Dermal Exposure from Contaminated Vegetation

In this acute exposure scenario, it is assumed that the chemical is sprayed at a given application rate and that an adult and child come in contact with sprayed vegetation shortly after the spray operation. In order to evaluate this, an estimate of the proportion of dislodgeable residue (PropDR) of the chemical is necessary. A PropDR of 0.1 (or 1/10 of the nominal applied rate) was used for all chemicals evaluated in this HHRA. This is based on the assumption that the PropDR of each chemical follows a pattern similar to that of 2,4-D (SERA, 2001). The PropDR is used to calculate the dislodgeable residue (DR) (**Equation 4-4c**) based on application rate(s) of each chemical.

Ingestion of Contaminated Fruits

For this exposure assessment, ingestion of contaminated fruits is evaluated under both acute and chronic exposure scenarios. Of the many possible scenarios that could be developed, these two accidental exposure scenarios assume accidental spraying of edible wild vegetation like berries. In both scenarios, the concentration of the chemical on contaminated vegetation is estimated. The concentration on fruit is estimated by the product of the residual deposition rate and the specific application rate(s) for each chemical. A residual deposition rate of 7 mg/kg per lb/acre for fruit (RR Fr) was obtained from Fletcher et al. (1994). For the acute scenario, the estimated concentration on fruit is the RR Fr multiplied by the application rate. For the chronic scenario, the estimated concentration on fruit is the product of RR Fr, the application rate, and the

proportion of application rate assuming a drift of 25 feet (obtained from AgDRIFT, refer to Section 4.2.3.2). A duration of 90 days was also used in the chronic scenario, and the rate of decrease in the residues over time was estimated from using a foliar half-life. The foliar half-lives were obtained from information provided by literature sources or default values from the GLEAMS modeling.

Ingestion of Contaminated Water

For this exposure assessment, two types of estimates were made for the concentration of the chemical in ambient water: 1) acute/accidental exposure; 2) and chronic, or longer-term, exposure. The acute/accidental exposure scenario assumes a young child ingests contaminated water shortly after an accidental spill of 25 gallons into a pond with a depth of 1 m and a surface area of 1,000 m^2. No dissipation or degradation is considered since exposure is assumed to occur shortly after the spill.

The chronic exposure scenario for ingestion of contaminated water over a longer period of time is evaluated using the results of GLEAMS. This environmental fate model was used to estimate ambient water concentrations in a 1 hectare by 2 m deep off-site pond. Section 3.3.1.2 provides a brief description of the GLEAMS model and the methodology for estimating ambient water concentrations for each chemical with the exception of methoprene (Altosid XR) and glyphosate-isopropylamine salt (Aquamaster), using GLEAMS data.

Ingestion of Contaminated Fish

This exposure assessment assumes fish from the off-site pond are consumed by an adult male and young child under both recreational and subsistence fishing scenarios. Estimates of chemical concentrations in ambient water are based on the data from the GLEAMS model. BCFs were conservatively calculated for each chemical using **Equation 3-25**. These BCFs represent whole-body portions for the fish. The chemical-specific K_{ow} values used in the BCF equation were taken primarily from data provided by chemical databases and manufacturers.

As mentioned previously, ingestion of contaminated fish was not evaluated as an acute exposure. This is because it is considered that, in general, residues in fish will not reach sufficient levels to cause significant exposures over short time scales.

4.3 DOSE-RESPONSE ASSESSMENT

For the active ingredient of each product used by TxDOT, a dose-response relationship was identified from available literature-based information while taking into consideration the study design, methodology, duration, endpoint, and test species. No observable effects levels (NOELs) can be identified from chronic toxicity studies, as well as reproductive and teratology studies. Reference doses (RfDs) may be obtained by dividing the NOEL by a safety factor. Safety factors make allowances for uncertainties in the data and may be used to reduce the NOEL to a level that would have a very low probability of producing adverse effects in humans. RfDs were obtained from USEPA to characterize risks associated with chemical exposures. USEPA was used as the primary source because of its reliance on approved scientific studies from which it gathers evidence to establish dose-response relationships. **Table 4-2** summarizes the acute and chronic RfDs, acute toxic and chronic systemic effects, and USEPA document references. In the cases where an acute RfD was not available from USEPA literature, the chronic RfD was used for the acute RfD.

4.4 RISK CHARACTERIZATION

In the risk characterization, levels of exposure (or dose) were compared to the RfD values summarized in **Table 4-2**. Acute and/or chronic risk estimates for a given pesticide-receptor combination were derived by dividing doses by the acute and/or chronic RfDs (i.e., toxicity values) summarized in **Table 4-2**. A ratio of 1.0 is used for comparison to the HQ (USEPA, 1990). Ratios less than 1.0 indicate that adverse noncarcinogenic health effects are unlikely. Ratios greater than 1.0 indicate that adverse noncarcinogenic health effects may occur at that exposure level. However, this does not mean that adverse effects will definitely occur, since the RfD incorporates safety and modifying factors to ensure that it is well below that dose for which adverse effects have been observed.

The risk characterizations for workers and general public are presented in the chemical-specific human health worksheets contained in Volume II, Appendix D. Risk estimates are based on chemical-specific application rates (expressed as lbs a.i./acre or lbs a.e./acre) used or planned for use by TxDOT for each product. When a given active ingredient is present and the same product applied at different application rates or in multiple products applied at different application rates, risk estimates are provided for each application rate and product used.

4.4.1 Workers

With the exception of triclopyr-BEE (Pathfinder II) and triclopyr-TEA (Garlon 3a), risk estimates for general exposures and dermal exposures (wearing contaminated gloves and accidental spill) involving a worker were less than 1.0. The HQ values for all exposure scenarios (general and dermal) evaluated for the worker exceeded 1.0 for triclopyr-BEE at 1.962 lbs a.e./acre and 3.924 lbs a.e./acre. As noted on the human health worksheet for triclopyr (Pathfinder II), these HQs ranged from 1.51 to 7,630. The most significant risks resulted from immersion of hands in solution for one hour (workers wearing contaminated gloves for one hour). Given the results of this risk assessment, it is important to ensure that TxDOT applicators follow TxDOT approved work practices and use the appropriate personal protection equipment to avoid the upper extremes of potential exposure associated with this chemical.

As noted on the human health worksheet for triclopyr (Garlon 3a), the HQ value for the worker under the general exposure scenario assuming boom-spray application of triclopyr-TEA (application rate of 0.75 lbs a.e./acre) also slightly exceeded 1.0 (HQ = 1.19). As mentioned previously, it is important that TxDOT applicators follow all label directions for personal protection, mixing, and application to avoid potential adverse effects associated with this scenario.

4.4.2 General Public

With the exception of chronic ingestion of fish contaminated with methoprene (Altosid-XR) by children of subsistence populations, risk estimates for acute direct spray, acute dermal contact with contaminated vegetation, acute and chronic ingestion of contaminated fruit, acute and chronic ingestion of contaminated water, and chronic ingestion of contaminated fish involving adults and young children were less than 1.0.

As noted on the human health worksheet for methoprene (Altosid XR), the HQ value (2.1) for the chronic ingestion of contaminated fish by children of subsistence populations exceeded 1.0. Therefore, the potential exists for this chemical to adversely effect the receptors evaluated in this scenario. TxDOT uses this chemical on a very limited basis, usually at the request of a local official for mosquito control. TxDOT prefers to minimize mosquito propagation within the ROW by maintaining adequate drainage, which reduces the available breeding habitat for mosquitoes.

TABLE 4-2
SUMMARY OF RFDS FOR PESTICIDE ACTIVE INGREDIENTS

Active Ingredient	Trade Name	RfDs		Reference	URL for Reference Document	Acute Toxicity/Chronic Systemic Toxic Effects
		Acute	Chronic			
Clopyralid	Transline	0.75	0.15	USEPA Pesticide Tolerance, Federal Register, September 25, 2002	http://www.epa.gov/fedrgstr/EPA-PEST/2002/September/Day-25/p24232.htm	Acute (Developmental Toxicity Study - rat. Maternal LOAEL = 250 mg ai/kg/day based on decreased weight gain during gestation days 6-9.) Chronic (2-yr chronic rat feeding study, LOAEL = 150 mg ai/kg/day based on increased epithelial hyperplasia and thickening of the limiting ridge of the stomach in both sexes.)
Fenoxycarb	Award	NA	0.8	USEPA Pesticide Tolerance, Federal Register, April 25, 1997	http://www.epa.gov/fedrgstr/EPA-PEST/1997/April/Day-25/p10749.htm	Chronic (2-year chronic toxicity/carcinogenicity study in rats with a NOEL of 8.1 mg/kg/day and an uncertainty factor of 100.)
Fluroxypyr	Vista	NA	0.8	USEPA Pesticide Tolerance, Federal Register, January 15, 2003	http://www.epa.gov/EPA-PEST/2003/January/Day-15/p848.htm	Based on chronic testing with fluroxypyr in the mouse, dog, and rat (two studies), an RfD of 0.8 mg/kg/day is proposed for fluroxypyr and fluroxypyr MHE. The RfD has incorporated a 100-fold safety factor to the NOAEL found in the rat chronic test. NOAELs found in the chronic dietary studies are as follows: 150 mg/kg/day (dog), 300 mg/kg/day (mouse), 80 mg/kg/day (Wistar rats), 100 mg/kg/day (male Fischer 344 rats), and 500 mg/kg/day (female Fischer 344 rats).
Glyphosate	Round up Pro & Aquamaster	NA	1.75	USEPA Pesticide Tolerance, Federal Register, September 27, 2002	http://www.epa.gov/fedrgstr/EPA-PEST/2002/September/Day-27/p24488.htm	Chronic (based on the maternal toxicity NOEL of 175 mg/kg/day from the developmental study with rabbits.)
Imazapyr	Habitat	NA	2.5	USEPA Pesticide Tolerance, Federal Register, September 26, 2003	http://www.epa.gov/EPA-PEST/2003/September/Day-26/p24123.htm	Chronic (1-Year Dog [feeding] Study. No LOAEL was demonstrated with imazapyr at doses up to 250 mg/kg/day (HDT); HIARC recommended for RA for imazapyr, based on skeletal muscle effects seen in dogs with structural analog imazapic)
Methoprene	Altosid XR	NA	0.4	USEPA RED, 1991	http://www.epa.gov/REDs/old_reds/methoprene.pdf	Chronic (Based upon a LEL for liver pigmentation at 150 mg/kg/day and a NOEL of 37.5 mg/kg/day in the 18-month mouse feeding/carcinogenicity study. UF=100.)
Metsulfuron methyl	Escort XP	NA	0.25	IRIS (USEPA, 1988)	http://www.epa.gov/iris/subst/0288.htm	Chronic (2-year rat feeding/oncogenicity study. Decreased body weight. NOEL=25 mg/kg/day. UF=100)
Sulfometuron methyl	Oust XP	NA	0.24	USEPA Pesticide Petition Filing, Federal Register, December 1997	http://pmep.cce.cornell.edu/profiles/herb-growthreg/sethoxydim-vernolate/sulfometuron-methyl/sulfo_pet_1297.html	Chronic (dietary rat study. Urinary bladder toxicity. NOAEL=24.4 mg/kg/day. UF=100)
Sulfosulfuron	Outrider	NA	0.24	USEPA Pesticide Tolerance, Federal Register, May 19, 1999	http://www.epa.gov/EPA-PEST/1999/May/Day-19/p12247.htm	Chronic (based on the rat chronic toxicity/carcinogenicity study NOAEL of 24.0 mg/kg/day and an uncertainty factor of 100.)
Triclopyr	Pathfinder II	1	0.05	USEPA RED, 1998	http://www.epa.gov/oppsrrd1/REDs/2710red.pdf	Chronic (based on the two-generation reproduction study in rats by Vedula et al. (1995) in which degeneration of renal proximal tubules were noted in adult animals at a dose of 25 mg/kg/day but not at 5 mg/kg/day. UF=100.) Acute (based on the NOAEL of 100 mg/kg/day from the study by Jones (1995) in which rats were administered gavage doses of triclopyr BEE)
	Garlon	1	0.05			
Sulfometuron methyl	Landmark MP	NA	0.24	see above	see above	see above
Chlorsulfuron (telar)		NA	0.02	USEPA Pesticide Tolerance, Federal Register, August 14, 2002	http://www.epa.gov/EPA-PEST/2002/August/Day-14/p20229.htm	Chronic (based on rat chronic toxicity/carcinogenicity LOAEL = 25 mg/kg/day based on decreased body weight in males. UF=300)
Amino pyralid	Milestone VM	NA	0.5	USEPA Pesticide Tolerance, Federal Register, August 10, 2005	http://www.epa.gov/fedrgstr/EPA-PEST/2005/August/Day-10/p15523.htm	Chronic (Chronic toxicity/carcinogenicity study. LOAEL= 500mg/kg/day based on cecal enlargement, slight mucosal hyperplasia in males and slightly decreased body weights. UF=100)

Notes:
LOAEL - Lowest observed adverse effect level
RfD - Reference dose
HDT - Highest tolerated dose
NA - Not Available. In these cases, the chronic RfD was used as the acute RfD for risk characterization purposes.
RED – Re-registration Eligibility Decision
NOEL - No observed effect level
USEPA - United States Environmental Protection Agency
UF - Uncertainty factor
IRIS - Integrated Risk Information System
NOAEL - No observed adverse effect level

Source: Project Team

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4.5 UNCERTAINTIES

The procedures used in this evaluation to assess risk to human receptors are subject to uncertainties because of the need to make certain assumptions and extrapolations. It is acknowledged that there are assumptions specific to the individual chemicals (e.g., estimated chemical/physical properties, field dilution rates, foliar half-lives, etc.) that contribute to the uncertainties of this HHRA. Due to the large number of active ingredient-product combinations presented in this document, uncertainties unique to the active ingredient and/or product that may have contributed to the over- or under-estimation of risk are not discussed. However, major uncertainties associated with the HHRA and their effect on risk conclusions are as follows:

Hazard Identification

- In making quantitative estimates of the toxicity of varying dosages of chemicals to human receptors, uncertainties arise from two sources. First, data on human exposure and the subsequent effects are usually insufficient, if they are at all available. Human exposure data usually lack adequate concentration estimations and suffers from inherent temporal variability. Therefore, animal studies are often used and new uncertainties arise from the process of extrapolating animal results to humans. Second, to obtain observable effects with a manageable number of experimental subjects, high doses of a compound are often used. In this situation, a high dose means that high exposures are used in the experiment with respect to most environmental exposures. Therefore, when applying the results of the animal experiment to human exposures, the effects at the high doses must be extrapolated to approximate effects at lower doses;
- In extrapolating effects from high doses in animals to low doses in humans, scientific judgment and conservative assumptions are employed. In selecting animal studies for use in dose-response calculations, the following factors are considered: 1) animal closely mimicking human pharmacokinetics; 2) dose intake most closely mimicking the intake route and duration for humans; and 3) demonstration of the most sensitive response to the compound in question. Also, for compounds believed to cause threshold effects (i.e., noncarcinogens), safety factors are employed in the extrapolation of effects from animals to humans and from high doses to low doses; and

- Another source of uncertainty related to the hazard identification is the use of chronic RfDs when acute RfDs were unavailable from USEPA-approved studies. This could result in an over-estimation of potential risks. Therefore, the fact that for most of the chemicals, there was only a chronic RfD available and it was used as an acute RfD adds a very significant level of conservatism to the final risk comparisons.

Exposure Assessment

- Certain potential exposure pathways and/or routes were not evaluated by this HHRA, including inhalation of spray particles, ingestion, or dermal contact with contaminated soil/sediment). Although potentially complete, these pathways were considered insignificant relative to other exposure pathways and/or routes that were evaluated. For this generic (i.e., non site- or species-specific) risk assessment, an attempt was made to limit the number of exposure scenarios to a reasonable number; and
- Another source of uncertainty related to the exposure assessment is the use of overly conservative exposure parameters. Although extremely conservative, these assumptions do serve to counter some of the uncertainty associated with limited toxicity test data for many of the chemical-receptor combinations.

Risk Characterization

- Risk estimates were derived on a compound-by-compound basis. That is, the risk assessment considered independent effects of chemicals. This could result in an under-estimation of risk for exposures to multiple chemicals if there are additive or synergistic effects. Furthermore, the risk assessment did not consider multiple application scenarios. This also could lead to an under-estimation of potential risks if multiple applications of a given formulation occur during the exposure periods assumed in this HHRA; and
- A second source of uncertainty associated with the risk characterization applies to the derivation of risk estimates on an exposure-by-exposure basis. As discussed in Section 4.2, in determining the level of exposure for the general public, two time scales were considered: 1) short-term (acute) exposures representing relatively high levels of exposure over a short period of time; and 2) long-term (chronic) exposures representing low levels of exposure over an extended period of time (i.e., 90-day exposure period beginning shortly after application and lifetime drinking water exposure). Both time scales included

exposure scenarios for the ingestion of surface water and ingestion of contaminated fruit. However, an overall ingestion dose was not obtained and used in the derivation of risk estimates. This resulted in an under-estimation of potential risks for each chemical-receptor combination with multiple ingestion pathways for a given time scale.

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